Aircraft Drafting

In the manufacture of this book, the publishers have observed the recommendations of the War Production Board and any variation from previous printings of the same book is the result of this effort to conserve paper and other critical materials as an aid to the war effort.

A Manual of
AIRCRAFT DRAFTING

By

CARL LARS SVENSEN, M.E.

Member-Secretary Texas State Board of Registration for Professional Engineers,
Registered Professional Engineer in Texas, Florida and New Mexico

SIXTH PRINTING

NEW YORK
D. VAN NOSTRAND COMPANY, INC.
250 FOURTH AVENUE

First Published Oct. 1941
Reprinted, April 1942, October 1942
February 1943, August 1943
February 1943, August 1943, May 1944

PRINTED IN THE UNITED STATES OF AMERICA

A Special Acknowledgment

TO ***John Ward Beretta***

CONSULTING ENGINEER, SAN ANTONIO, TEXAS

FOR HIS ACTIVE INTEREST AND HELP. HIS PIONEERING ASSOCIATION WITH THE MANY PHASES OF AVIATION AND HIS MANIFOLD CONTACTS WITH LEADERS IN THE INDUSTRY HAVE BEEN A MEANS OF INCREASING THE SCOPE AND VALUE OF THIS BOOK.

PREFACE

Aircraft Drafting is based upon the general principles of graphic description. However, drafting practices have developed in the aviation industry to meet the requirements of design layouts, lofting, standard parts (AN, commercial and company), specifications, notes, dimensions, representation, manufacture, fabrication, installation, etc. All of this constitutes a distinctive procedure which has become standardized in aircraft drafting rooms but has not been made generally available for text and reference use. Recognition of the importance of Aircraft Drafting and the demand for a book on this subject, are the reasons for this treatise.

This book is devoted to the one subject of Aircraft Drafting. It is a complete treatise covering both the fundamentals and their application in the aviation industry. A previous course in mechanical drawing is not required. The first chapters give the necessary instructions for the use of the graphic language. The later chapters cover the applications and practices as used in the aircraft drafting rooms throughout the United States.

A dash system of numbering (in keeping with aircraft practice) has been used for articles, illustrations, and problems to facilitate identification and for convenience in reference.

The number of problems is ample to meet the requirements of intensive short courses or extensive long courses, and for either drafting or reading courses, or as a part of courses in aeronautical engineering.

The illustrations and the drafting problems are the result of the active and valuable cooperation of aircraft companies and authorities from all parts of the country. This universal participation has resulted in a book of greater value than could be attained in any other way.

The excellence of the illustrations is due to the personal interest and painstaking care of Mr. Herbert Brasher (in charge of the author's drafting room) who cooperated in every way in the preparation of this book. The active interest and technical services of Mr. Douglas W. Ross, Jr., added greatly to the value and accuracy of both text and problems. Appreciation is expressed to Mr. Fred E. Rightor and Mr. A. F. Mitchell, fellow members of the Texas State Board of Registration for Professional Engineers, for helpful suggestions. Definite contributions and active assistance have come from so many sources — executives, aeronautical engineers, and other authorities as well as aircraft and related companies — that a list of acknowledgments is included in lieu of specific statements of indebtedness. It is hoped that there are no omissions but should there be any, the author's appreciation is no less sincere.

Lubbock, Texas
July, 1941

C. L. S.

ACKNOWLEDGMENTS

APPRECIATION for cooperation and assistance is here expressed to the men and organizations listed and to all others who have contributed in any way to making the publication of this book possible at this time.

A. A. Anderson, Portland Cement Association
J. L. Atwood, Vice President, North American Aviation, Inc.
W. E. Beal, Chief Engineer, Boeing Aircraft Company
Jerome J. Boyd, Stinson Aircraft, Division of Vultee Aircraft, Inc.
Willis C. Brown, President, Southern Aircraft Corporation
E. J. Burns, Chief Draftsman, Piper Aircraft Corporation
W. W. Burrows, Engineering Department, Lycoming Division, Aviation Manufacturing Corporation
James L. Camp, Pratt and Whitney Aircraft Division, United Aircraft Corporation
G. P. Clericuzio, Eclipse Aviation, Division of Bendix Aviation Corporation
H. I. Crow, Air Associates, Inc.
E. W. Dichman, Vought-Sikorsky Aircraft, Division of United Aircraft Corporation
Lloyd K. Eagle, Aluminum Company of America
Major Donald F. Fitch, Air Corps, Exec., Mat. Div., War Department
E. L. Fithian, Eugene Dietzgen Co.
R. S. Greenwald, Assistant Standards Engineer, North American Aviation, Inc.
Major Merwin E. Gross, Air Corps, Exec., Mat. Div., War Department
Andrew F. Haiduck, Chief Engineer, Bellanca Aircraft Corporation
W. A. Hite, Chief Engineer, Interstate Aircraft & Engineering Corporation
Dan C. Hungerford, Elastic Stop Nut Corporation
L. M. Kowalski, Aero Supply Manufacturing Corporation
J. G. Kuhn, Kinner Motors, Inc.
Jerome Lederer, Director, Safety Bureau, Civil Aeronautics Board
W. R. Macatee, The Asphalt Institute
Orin Moe, Chief Engineer, Southern Aircraft Corporation
W. C. Moser, National Tube Company
S. A. McClellan, Ranger Aircraft Engines
Svend Pedersen, Manager Education Service, Industrial Relations Office, Lockheed Aircraft Corporation
E. E. Price, Eugene Dietzgen Co.
Frederick C. Pyne, Aircraft Development Engineer, Aluminum Company of America
R. H. Rice, Chief Engineer, North American Aviation, Inc.
Harry T. Rowland, The Glenn L. Martin Company
C. P. Sander, Chief Engineer, Kinner Motors, Inc.
Wm. R. Skinner, Chief Engineer, Porterfield Aircraft Corporation
J. S. Smith, Wright Aeronautical Corporation
John H. Stephens, President, Apec Company
Frank Sunderland, Taylorcraft Aviation Corporation
H. V. Thaden, Aeronautical Engineer, Hayes Manufacturing Company
Fred E. Weick, Chief Engineer, Engineering and Research Corporation
A. E. Zipprich
Aero Supply Manufacturing Co., Inc.
Air Associates, Inc.

Aluminum Company of America
American Society of Mechanical Engineers
American Standards Association
American Welding Society
Asphalt Institute
Bellanca Aircraft Corporation
Boeing Aircraft Company
Brewster Aeronautical Corporation
Curtiss Aeroplane Division, Curtiss-Wright Corporation
The Dow Chemical Company
Eclipse Aviation, Division of Bendix Aviation Corporation
Elastic Stop Nut Corporation
Engineering and Research Corporation
Hamilton Standard Propellers
Harvill Aircraft Die Casting Corporation
Interstate Aircraft & Engineering Corporation
Kinner Motors, Inc.
The Lincoln Electric Company
Lockheed Aircraft Corporation
The Glenn L. Martin Corporation
National Advisory Committee for Aeronautics
National Tube Company
New York Public Library
North American Aviation, Inc.
Porterfield Aircraft Corporation
Ranger Aircraft Engines, Division of Fairchild Engine & Airplane Corporation
Society of Automotive Engineers
Southern Aircraft Corporation
Stinson Aircraft, Division of Vultee Aircraft, Inc.
Taylorcraft Aviation Corporation
U. S. Coast & Geodetic Survey
U. S. Department of Commerce, Civil Aeronautics Administration
U. S. Geological Survey
J. H. Williams & Co.
Wright Aeronautical Corporation

CONTENTS

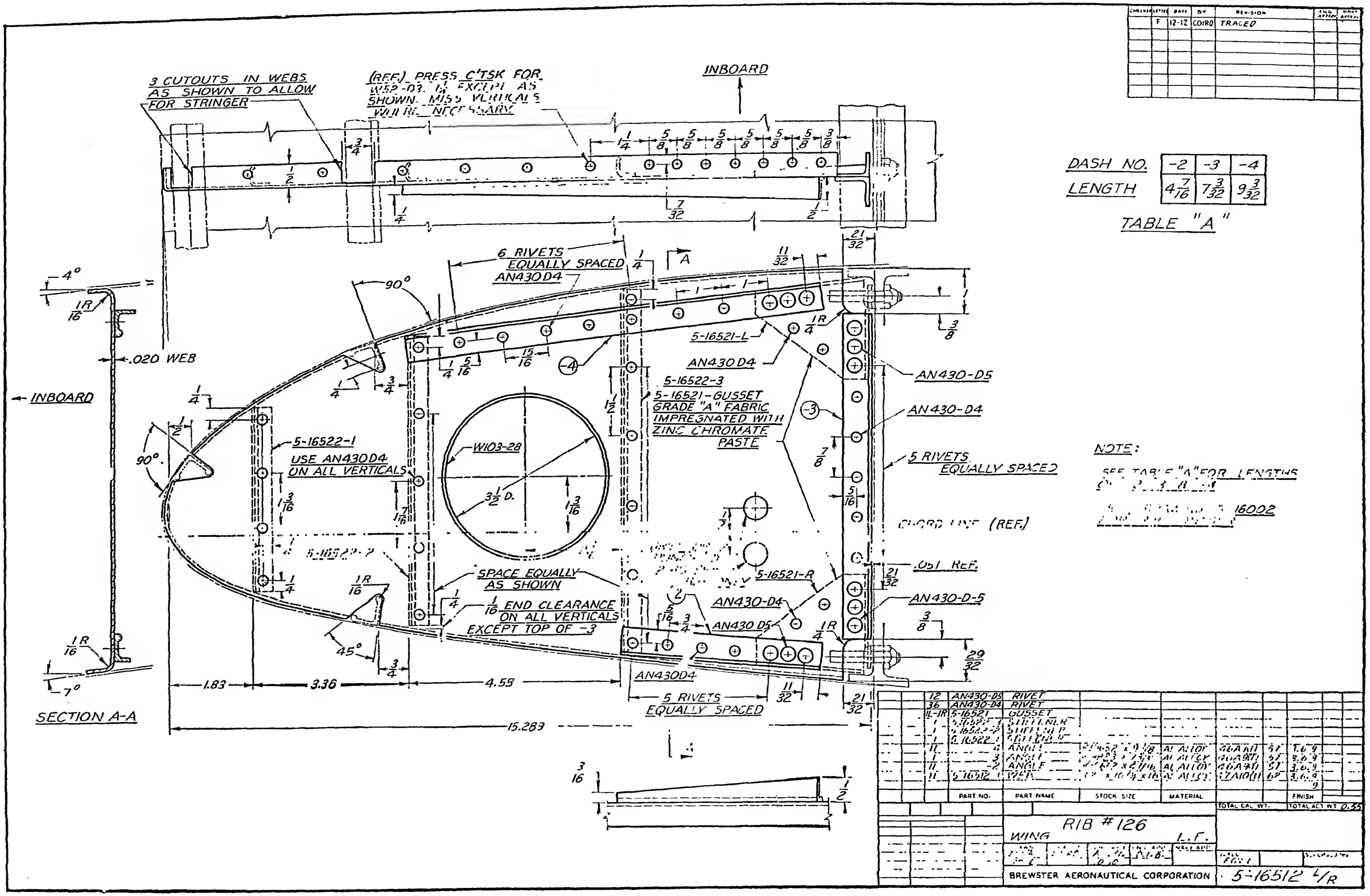


FIG. 1-1. An Aircraft Drawing.

CHAPTER I

AERONAUTICAL ENGINEERING

1–1. In the early days of the aviation industry airplanes were " built " and the experimental factor was always present to a large degree. Experience, research and the growth of aeronautical science have made possible the present aviation industry in which aircraft are manufactured. In all of this aircraft drafting is essential for improvements in design, for new designs, for the study of proposed changes, for all the possibilities of manufacture and use including

Fig. 1–2. Drafting Room, Pratt & Whitney, Aircraft Division, United Aircraft Corporation.

detail drawings of separate parts, assembly of parts, provision for installation of parts and equipment, erection, maintenance and the form of the complete aircraft. In fact manufacture and progress would be impossible without aircraft drafting to give and to record the necessary graphic descriptions (Fig. 1–1).

1–2. Between the drawing board of Fig. 1–2 and the airport of Fig. 1–3 are many hours of drafting by hundreds of aeronautical engineers, designers and draftsmen, and thousands of drawings.

The fundamentals of all drafting are very much alike but the application to aircraft has introduced many features which have had to be modified and coordi-

nated in a single design. Some of the aircraft drafting practices have come from structural engineering, some from automobile engineering, some from marine engineering, some from textile engineering, some from all the various other branches of engineering, and all of them have had to be adapted to the requirements of strength and power with light weight and the use of many new materials.

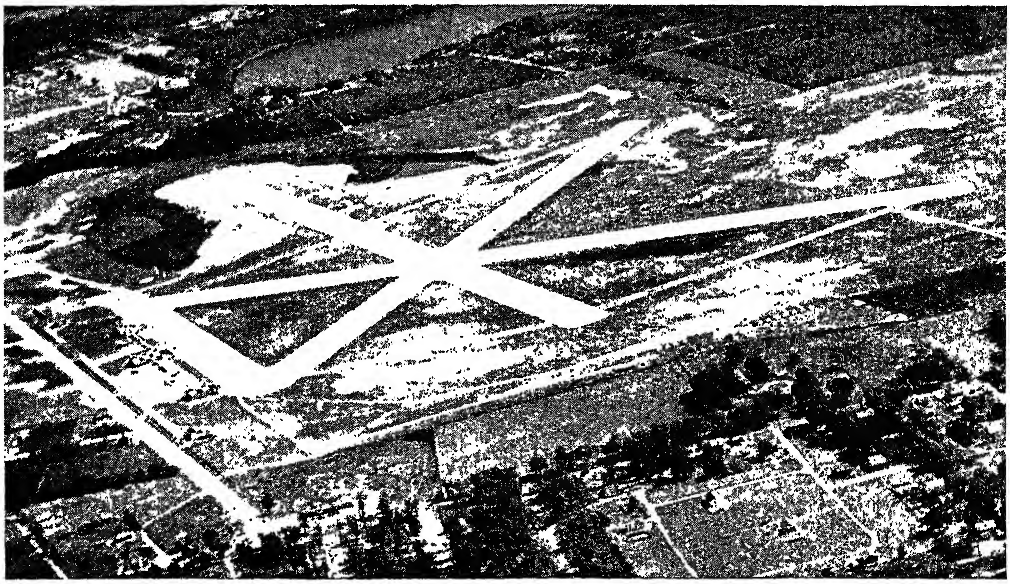


FIG. 1–3. Rhode Island State Airport, Providence (Hillsgrove), R. I.
(Photo by Portland Cement Association)

1–3. The whole field of aeronautical engineering passes over the drawing board and into the drawings from which aircraft are made. Thus it is that the study of aircraft drafting provides a most valuable means of entering the industry and of obtaining a thorough understanding of all that is involved in the manufacture of airplanes.

CHAPTER II

HOW TO USE DRAFTING EQUIPMENT

2–1. The usual drafting equipment (Fig. 2–1) consists of drawing board or drawing table top, T-square, a 30°–60° triangle, a 45° triangle, scale, irregular curve, protractor, and a set of " case instruments." Supplies include drawing paper, tracing paper, thumb tacks or other fastening means, pencils (H or F for lettering and 2H and 4H for drawing), pencil pointer, pencil eraser and art gum, and black drawing ink and pens (ball point and 404 Gillott's) if inking is required.

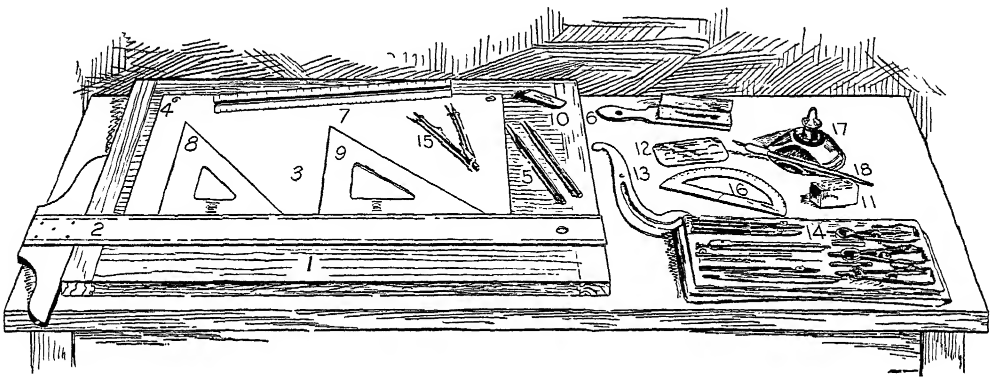


Fig. 2–1. Drafting Equipment.

1. Drawing board
2. T-Square
3. Drawing paper
4. Thumb tack
5. Pencils
6. Pencil pointer
7. Scale
8. 30°–60° Triangle
9. 45° Triangle
10. Pencil eraser
11. Art gum
12. Erasing shield
13. Irregular curve
14. Case instruments
15. Compasses
16. Protractor
17. Drawing ink
18. Pen and holder

Parallel ruling straight edges (Fig. 2–2) and drafting machines (Fig. 2–3) are rapidly becoming standard equipment in engineering drafting rooms. The drafting machine combines the most used drawing tools (T-square, triangles, scale and protractor).

2–2. Pencils should be sharpened by cutting away the wood with a knife, or draftsmen's special cutter, as at *A* and *B* in Fig. 2–4. Then shape the lead to a long conical point as at *C* using a sandpaper pad, file or special pointer. Wedge or " screw-driver " points, shown at *D* and *E*, are preferred by some draftsmen. The points shown at *F* and *G* are often used in the compasses.

2–3. Drawing paper is fastened to the drawing board by thumb tacks as in Fig. 2–5, by Scotch tape as in Fig. 2–2, or other means such as wire staples. If the paper is not over 12″ × 18″ it may be held by two thumb tacks in the

upper corners. Drawings which have to stand up under repeated printings and frequent handling should be made on pencil tracing cloth, especially large or roll

FIG. 2–2. Premier Parallel Ruling Straight Edge. (*Eugene Dietzgen Co.*)

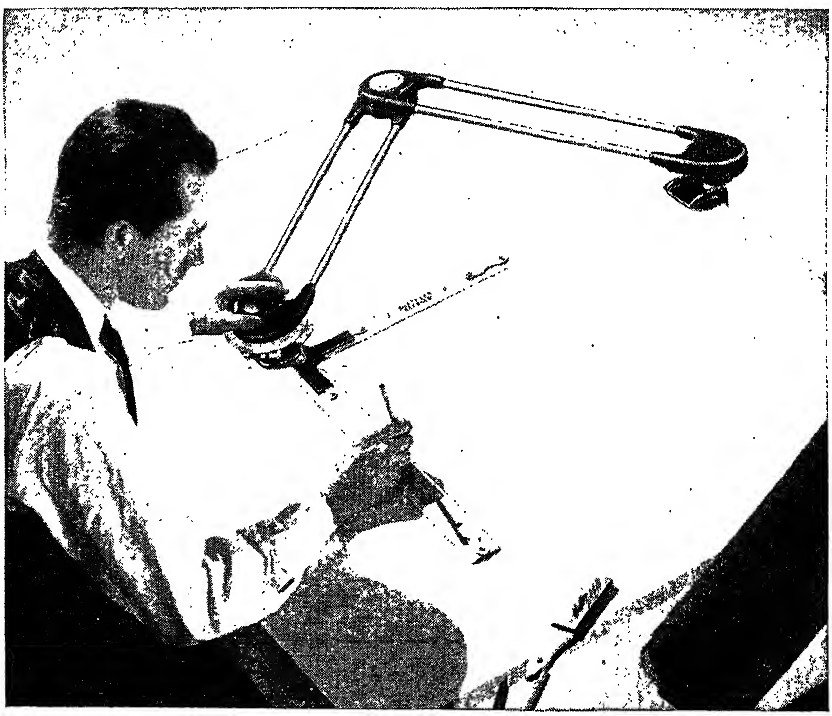


FIG. 2–3. Excello Drafting Machine. (*Eugene Dietzgen Co.*)

size drawings such as wing or tail erection drawings, aileron assembly, stabilizer assembly, fuselage skeleton, engine mount, power plant installation, etc. For

other drawings, pencil lines on vellum or tracing paper are generally used, unless ink tracings are specifically required as for certain Government work. Tracing paper or cloth must be fastened at four or more places to hold it in position.

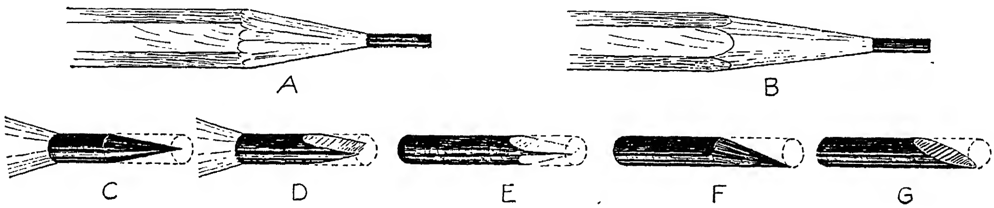


FIG. 2-4. Pencil Points.

2-4. Horizontal Lines. — The T-square (Figs. 2-5 and 2-6) is used to square up the paper, for drawing horizontal lines, and for placing the triangles in position. Hold the head of the T-square against the left-hand[1] edge of the board and move it up or down, to the desired position. The parallel ruling straight edge (Fig. 2-2) and the drafting machine (Fig. 2-3) are quicker and more convenient for drawing horizontal lines.

Always use the upper edge of the blade or straight edge to guide the pencil, which is moved from left to right.

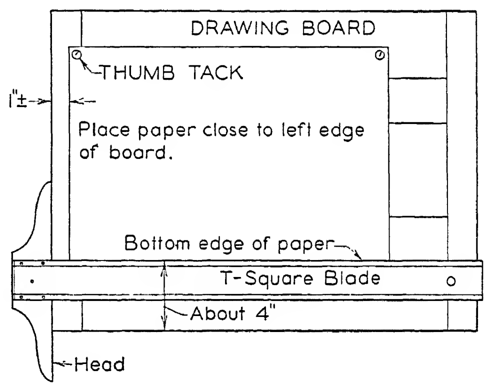


FIG. 2-5. Placing and Fastening the Paper.

2-5. Vertical and Inclined Lines. — The triangles may be used in connection with the parallel ruling straight edge or T-square to draw vertical lines and lines making multiples of 15° with horizontal or vertical lines. Vertical lines are drawn by placing a triangle against the upper edge of the T-square blade (vertical edge is to the left) and drawing upward as illustrated in Fig. 2-7. Positions for drawing angles of 30°, 60°, 45°, 15°, and 75° are shown in Figs. 2-8 and 2-9.

The drafting machine (Fig. 2-3) is more desirable as it provides a direct method of drawing horizontal, vertical or inclined lines.

2-6. To Draw Parallel Lines. — *With the drafting machine:* Set the ruling edge to the given line, move to the desired new position and draw the parallel line. *With the triangles or triangle and T-square:* Given a line as at *A* (Fig. 2-10), place a triangle in position so that one edge matches the line as at *B*. Place the T-square blade or a second triangle against another edge as at *C*. Hold the T-square blade or triangle firmly in place, slide the first triangle to the desired new position as at *D* and draw the parallel lines.

[1] For a left-handed person use *right* for *left* and *left* for *right* in these instructions.

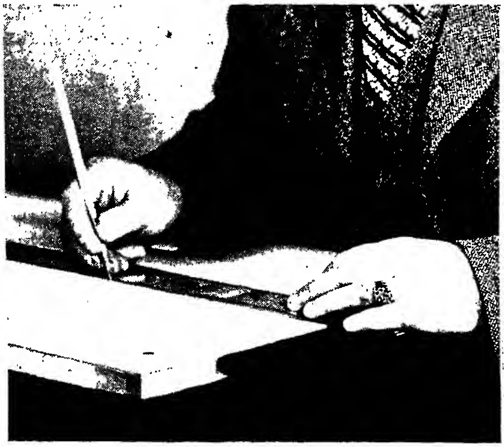


FIG. 2–6. Drawing Horizontal Lines.

FIG. 2–7. Drawing Vertical Lines.

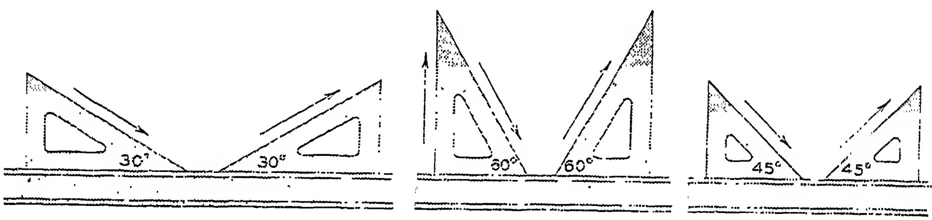


FIG. 2–8. Triangles

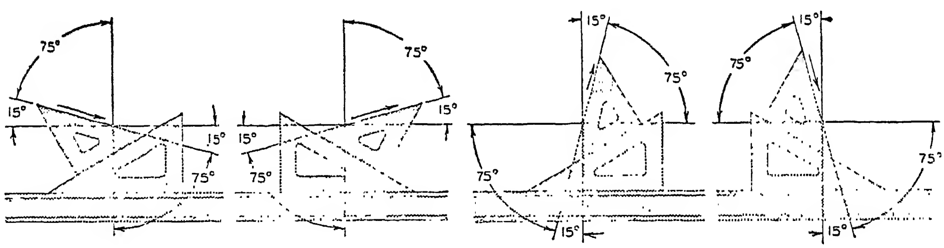


FIG. 2–9. Angles of 15° and 75°.

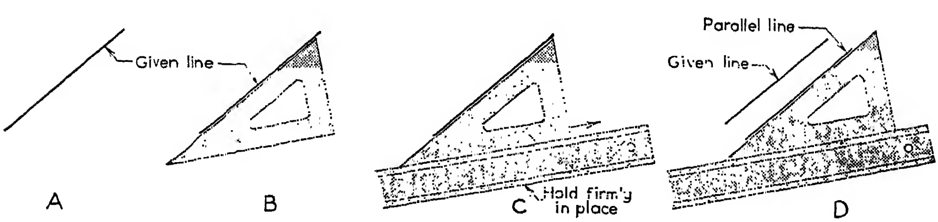


FIG. 2–10. To Draw Parallel Lines.

2–7. To Draw Perpendicular Lines. — *With the drafting machine:* Set one ruling edge to the given line, move to new position and draw the perpendicular line with the other ruling edge in the desired position. *With the triangles or triangle and T-square:* Given a line as at *A* (Fig. 2–11), place a triangle in position so that its hypotenuse (or long edge) matches the line as at *B*. Place the T-square as at *C*. Hold the T-square blade or a second triangle in place and turn the first triangle about its right angle corner to the position shown at *D* and draw the perpendicular line along the hypotenuse.

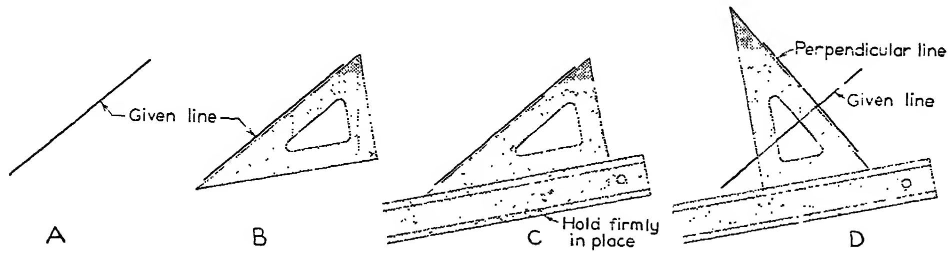


FIG. 2–11. To Draw Perpendicular Lines.

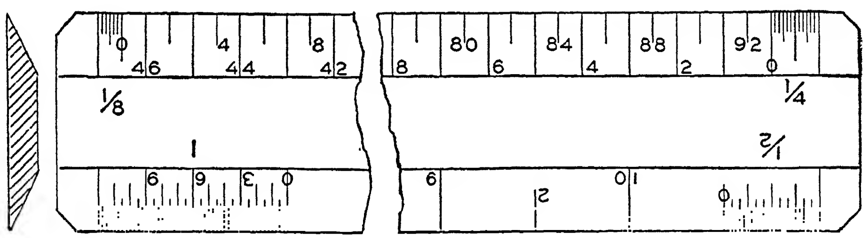


FIG. 2–12. Flat Scale.

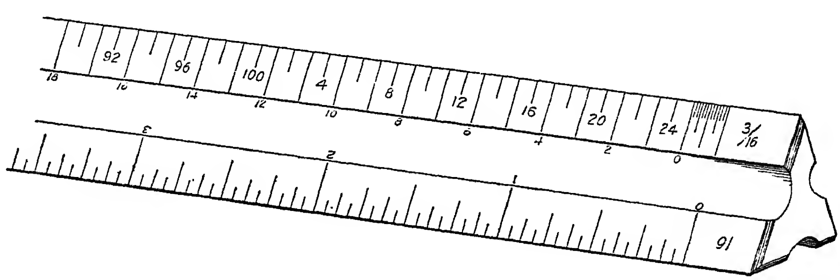


FIG. 2–13. Triangular Scale.

2–8. The scale is used to make, or lay off, measurements on drawings. Most engineers prefer some form of flat scale (Fig. 2–12). The mechanical engineers' open divided scale shown has four scales proportionally divided to represent feet and inches. The triangular scale shown in Fig. 2–13 is often used in schools to

save the expense of a set of flat scales. To use the scale, place it parallel to the direction of measurement and make short marks opposite the desired divisions on the scale (Fig. 2–14). When the drafting machine is used the scales are always in position and lines can be drawn the desired lengths at once. The ¼ scale or " quarter size " (3″ = 1′) means that one-fourth inch on the drawing represents one inch on the object. In this case a distance equal to three inches is divided into twelve parts, each of which represents one inch. Each of the twelve parts is further divided to represent the fractions of an inch. Distances measured with the different scales are shown in Fig. 2–15. Separate flat scales are preferred by most engineers. A " half-size " scale (6″ = 1′) is sometimes convenient. With the full-size scale use the half inch as an inch for half-size drawings, the quarter inch as an inch for quarter size drawings, and so on for other reductions. Never divide the dimensions of the piece when drawing to a reduced scale, measure with the reduced scale but think full size.

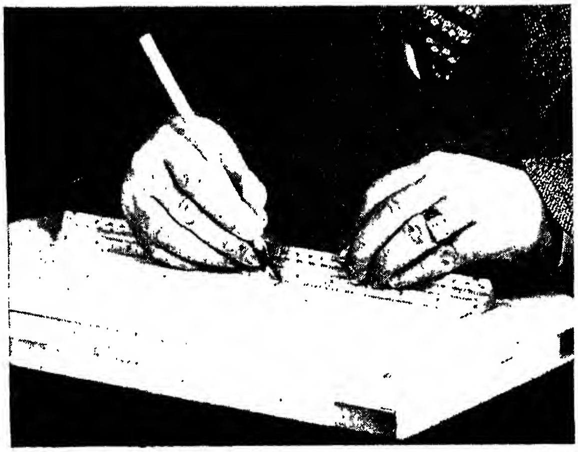


Fig. 2–14. Laying off a Measurement.

Scales are made with the inches divided into decimal parts. Metric scales are also made for use when measurements are made in millimeters.

2–9. Irregular curves (Fig. 2–16) are used, by trial, to draw curved lines other than arcs of circles. Locate the points through which the curve is to pass and sketch a freehand curve through them. Select a suitable irregular curve, a portion of which is then matched to a part of the freehand curve. Draw this part of the curved line and move the irregular curve to a new position. The irregular curve should always be placed so that its increasing radius is in the same direction as the increasing radius of the curve being drawn.

Adjustable curve rulers (Fig. 2–17) will hold the curve to which they are bent. Splines and ducks or weights (Fig. 2–18) are used for drawing long curved lines such as wing profiles, cowl lines, etc.

2–10. The protractor, used for measuring or laying out angles, is shown in Fig. 3–4.

2–11. The " case instruments " are illustrated in Fig. 2–19. The compasses (Fig. 2–20) are used for drawing circles and arcs. For large circles (radius of 2″ or more) and when inking, the legs should be perpendicular to the paper (Fig. 2–21). The needle point should be adjusted with the shoulder point downward and so that the point extends slightly beyond the pen or pencil point.

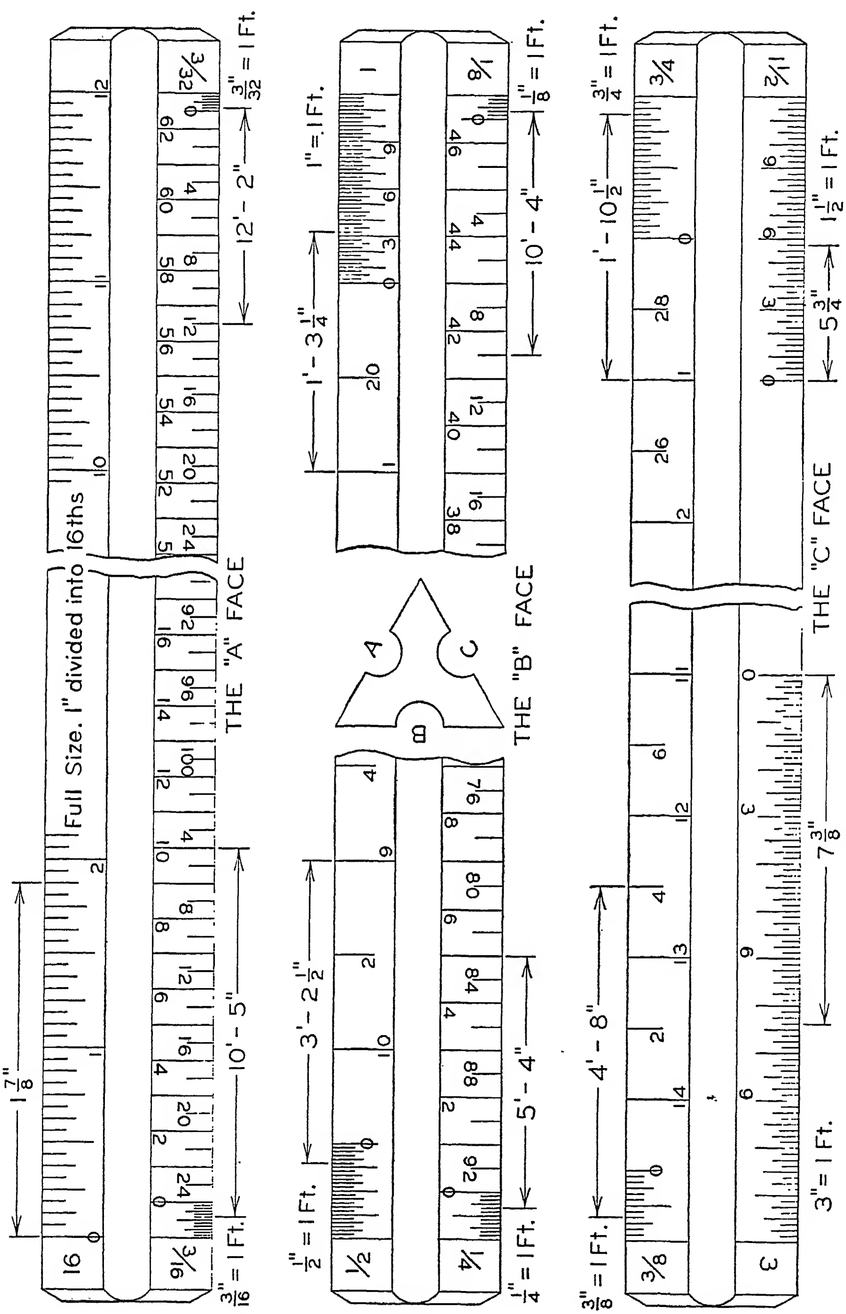


Fig. 2–15. Measurements to Scale.

The lengthening bar (Fig. 2–22) is used to extend one leg of the compasses when the radius is more than 4″ or 5″. Beam compasses are made for use for extra long radii (see drafting supply catalogs). The dividers (Fig. 2–23) are used for transferring measurements, for dividing lines (straight and curved) and for "stepping off" distances. To divide a line or arc into a number of equal parts (say six) set the points of the dividers to a distance estimated to be one-sixth of

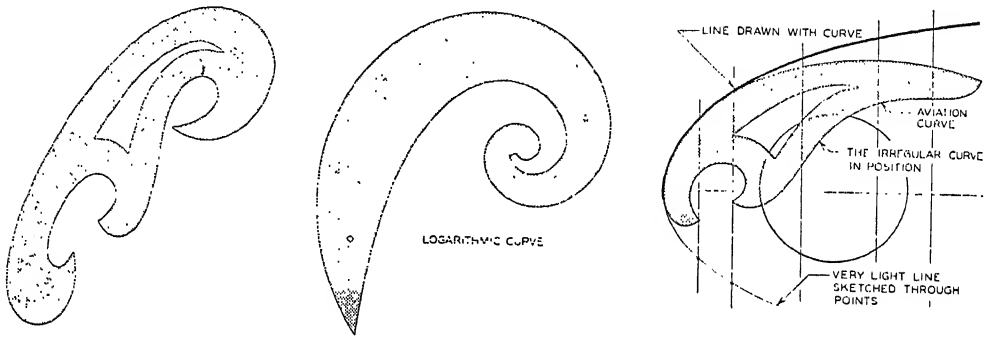


Fig. 2–16. Irregular Curves.

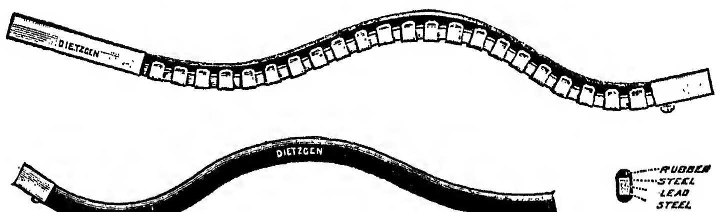


Fig. 2–17. Adjustable Curve Rulers.

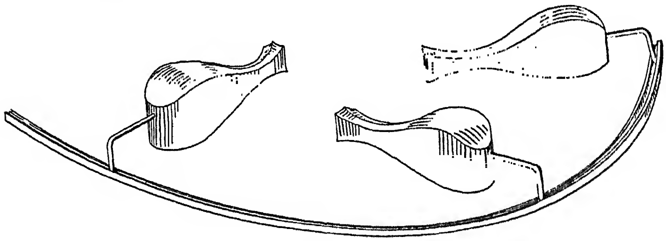


Fig. 2–18. Spline and Weights.

the length of the line or arc. Place a point of the dividers on the end of the line and "step off" six spaces (revolving the points in opposite directions as shown). If too short or too long, decrease or increase the distance between the points of the dividers.

The bow dividers are used for the same purposes as the large dividers but for small spaces. The bow pencil and bow pen are used for drawing arcs and circles when the radius is small.

2–12. Most drawings are now made directly in pencil on tracing paper or vellum or for permanent or severe usage on pencil tracing cloth. For some purposes drawings are inked on paper or traced in ink on tracing cloth with a

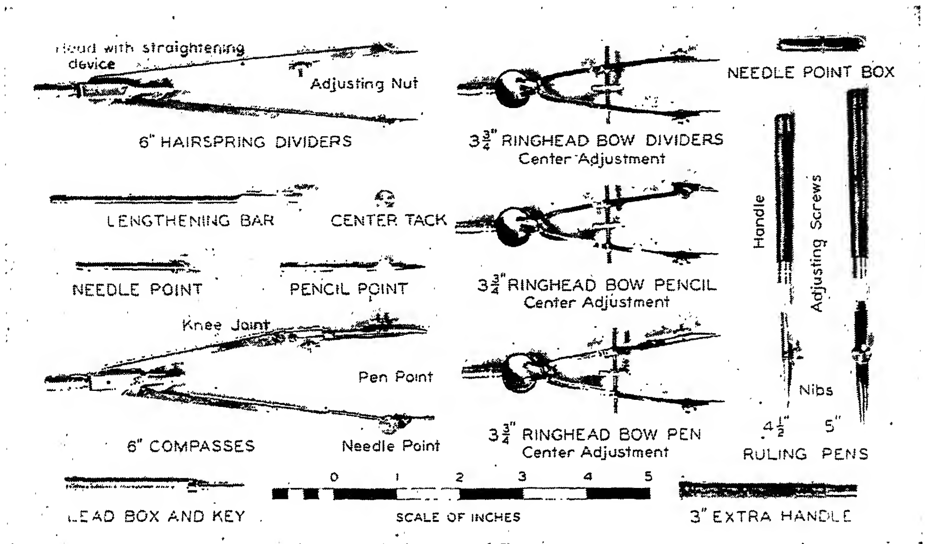


Fig. 2–19. The Case Instruments.

ruling pen (Fig. 2–24). Black water-proof drawing ink is used. It is placed between the nibs or blades of the ruling pen, or pen point of the compasses, with

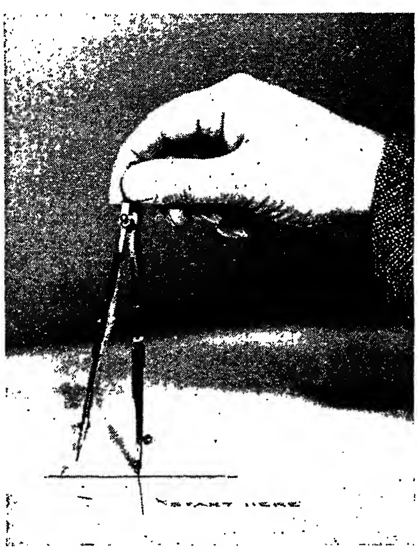


Fig. 2–20. Using the Compasses with Pencil Point.

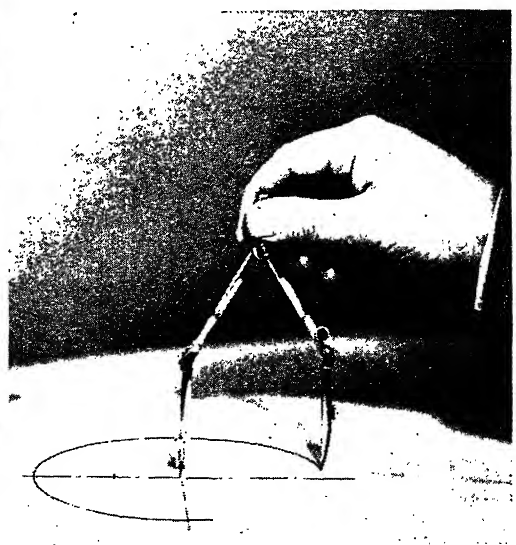


Fig. 2–21. Using the Compasses with Pen Point.

the quill attached to the ink-bottle stopper. Use a small amount of ink and turn the adjusting screw until the desired width of line is obtained. The ruling pen should be held with the inside (or stiff blade) against the T-square or triangle for straight lines and against the irregular curve for curved lines. The compasses, with pen-point insert, and the bow pen are used for inking arcs and circles. Keep the pen points clean at all times.

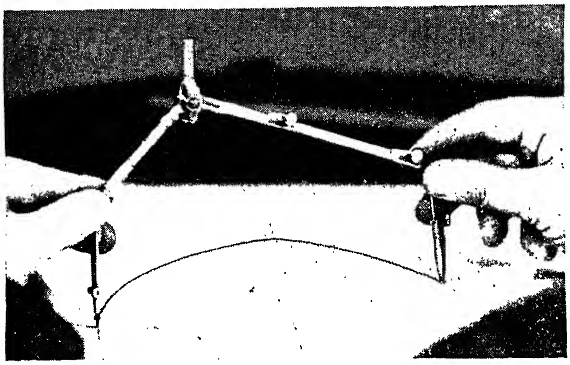


Fig. 2-22. The Lengthening Bar.

2-13. Line Symbols.—American Standards[2] as illustrated in Fig. 2-25 suggest the following:

"Three weights of lines, heavy, medium, and light are considered desirable on finished drawings in ink, both for legibility and appearance, although in rapid practice and in particular on penciled drawings from which blue prints are to be made this may be simplified to two weights medium and light. For pencil drawings the lines should be in proportion to the ink lines, 'medium' for outlines, hidden, cutting planes, short breaks, adjacent part and alternate position lines and 'light' for section, center, dimension, long break, and ditto lines."

Fig. 2-23. The Dividers.

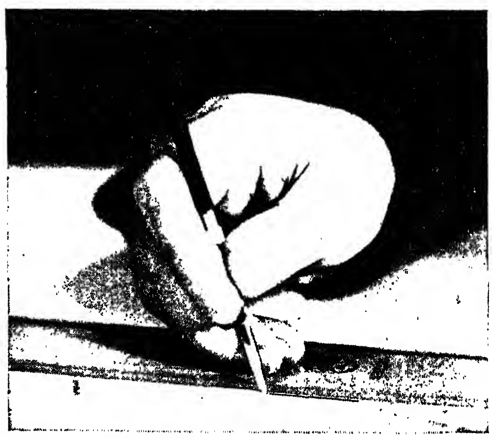


Fig. 2-24. Using the Ruling Pen.

The character and weight of lines illustrated in Fig. 2-26 are standard for either pencil or ink drawings, in many aircraft drafting rooms. Light lines are

[2] The American Standards Association, 29 West 39th Street, New York, N. Y.

made sufficiently dense to assure good reproduction. Hidden lines except for very small parts are made at least $\frac{3}{16}$ to $\frac{1}{4}$ inch long in the interest of speed.

2–14. Erasing of pencil or ink lines may be done with a red or green pencil eraser. Electric erasing machines (Fig. 2–27) are convenient, save time and

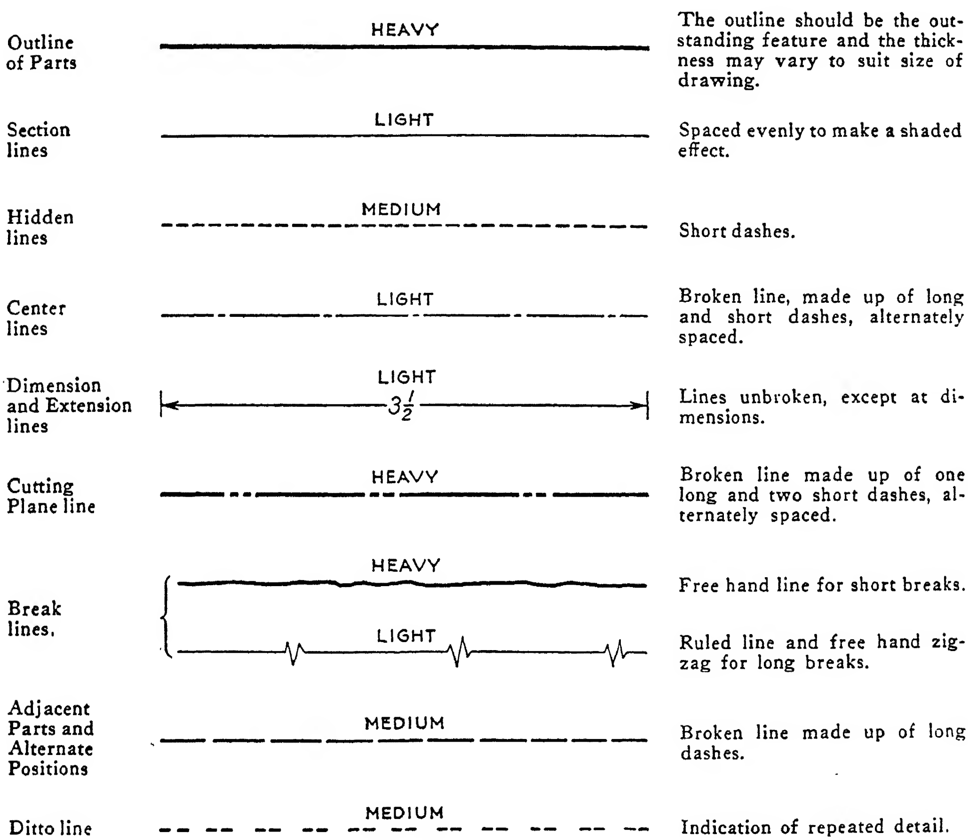


FIG. 2–25. American Standard Line Symbols.

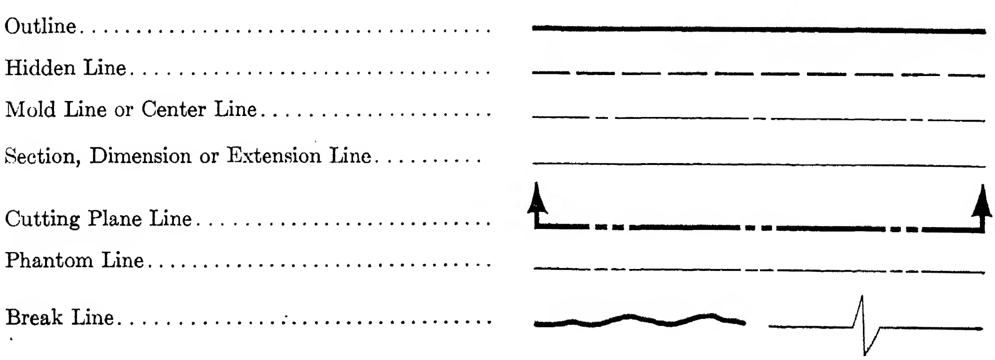


FIG. 2–26. Line Symbols.

give good results when carefully handled. Erasing shields of celluloid or metal are useful to protect lines which are not to be removed. Art gum is used for erasing light pencil lines and for cleaning the drawing.

2–15. Other instruments which are both convenient and useful in aircraft drafting and design include slide rules for making calculations, pantographs for enlarging or reducing drawings, and planimeters for measuring areas.

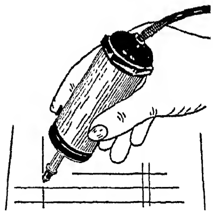


Fig. 2–27. Erasing Machine.

2–16. Preliminary Instructions for Problems. — Most of the problems in the early chapters of this book can be drawn on an 11″ × 17″ standard size sheet with one of the layouts suggested in Figs. 2–28, 2–29, and 2–30 or in a division of the space (Fig. 2–31). An inspection of the problem will indicate the proper space where it is not specified. When other sizes are necessary a standard size sheet should be used (refer to Fig. 9–6).

A title should be put on every drawing and may be similar to the forms suggested in Figs. 2–32 and 2–33 or to suit the requirements of the instructor.

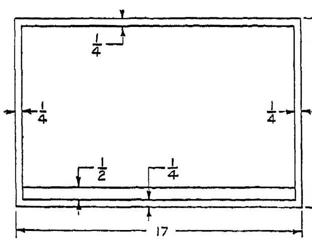


Fig. 2–28.

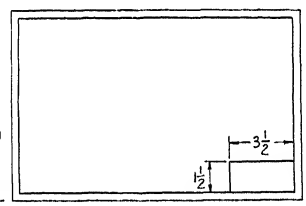


Fig. 2–29.

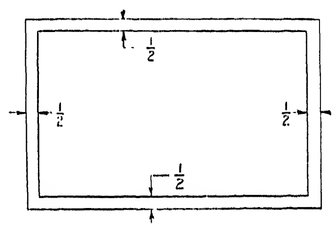


Fig. 2–30.

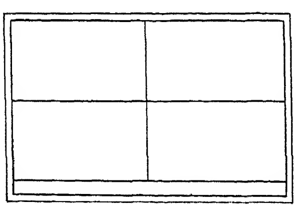


Fig. 2–31.

Fig. 2–32.

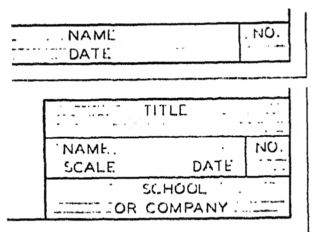


Fig. 2–33.

2–17. Practice Exercises. — Practice exercises are valuable for acquiring accuracy, proper methods of handling instruments, and improving the quality of pencil and ink work. Sharp pencil lines, accurate measurements and a minimum of erasing should be maintained in all work.

This chapter should be carefully studied before beginning the exercises and frequent reference should be made to the illustrations and descriptive matter while working on the exercises.

After fastening the paper in place draw the margin lines and divide the working space into four equal spaces. Work one exercise in each space. Dimensions are given in inches unless otherwise specified. Inch marks (″) are not used. Dimensions and lettering are not to be put on the student's drawings.

Prob. 2-1. Fig. 2-34. — Draw a 4 × 6 rectangle. Divide *AD* into 4 equal parts and *DC* into 6 equal parts, using the scale. Draw horizontal and vertical lines. Refer to Arts. 2-4, 2-5, and 2-8.

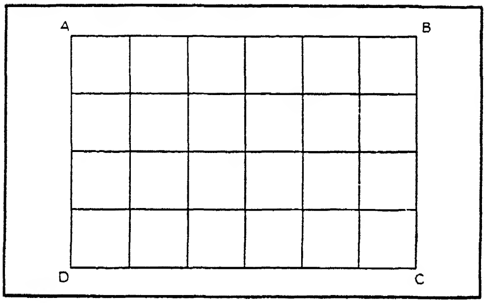


FIG. 2-34. Prob. 2-1.

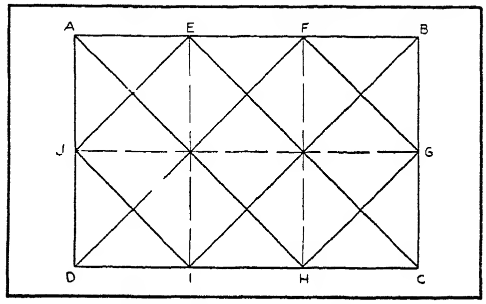


FIG. 2-35. Prob. 2-2.

Prob. 2-2. Fig. 2-35. — Draw a 4 × 6 rectangle and divide it into 6 equal squares with very light lines. Draw 45° lines with the 45° triangle and T-square. Refer to Arts. 2-4 and 2-5.

Prob. 2-3. Fig. 2-36. — Draw a 4 × 6 rectangle. Locate the mid-points of the sides *E*, *F*, *G* and *H*. Draw 30° and 60° lines with the 30°-60° triangle and T-square. Refer to Arts. 2-4 and 2-5.

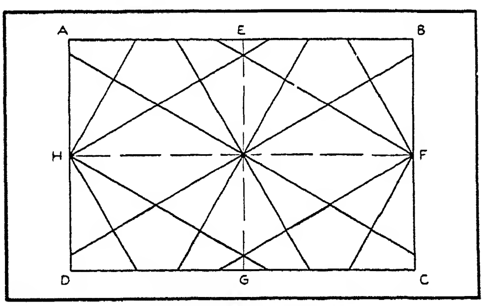


FIG. 2-36. Prob. 2-3.

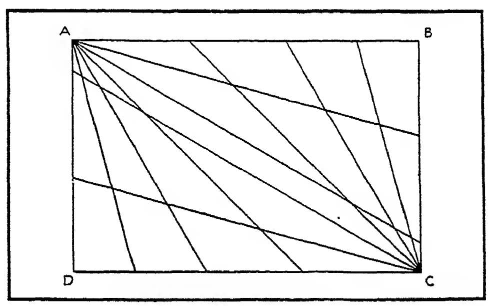


FIG. 2-37. Prob. 2-4.

Prob. 2-4. Fig. 2-37. — Draw a 4 × 6 rectangle. Draw lines at 15°, 30°, 45°, 60° with the sides of the rectangle, from corners *A* and *C*.

Prob. 2-5, 2-6, 2-7, 2-8. Draw the flight path diagrams as indicated. Assume proportions. Fig. 2-38 is for *S* turns across a road. Fig. 2-39 is for an *eight* along a road. Fig. 2-40 is for an *eight* across a road. Fig. 2-41 is for a *four bank eight* across a road.

Prob. 2-9. Fig. 2-42. — Locate the center of the space. Draw the four vertical lines. Draw circles with diameters of 1½, 2, 2½, 3, 3½ and 4 as shown.

Prob. 2-10. Fig. 2-43. — Draw the layout for the carburetor flange as shown. (S.A.E. Standard, Society of Automotive Engineers.)

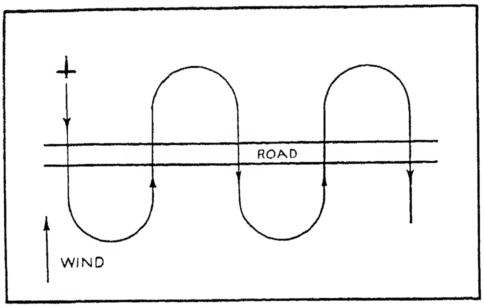


Fig. 2-38. Prob. 2-5.

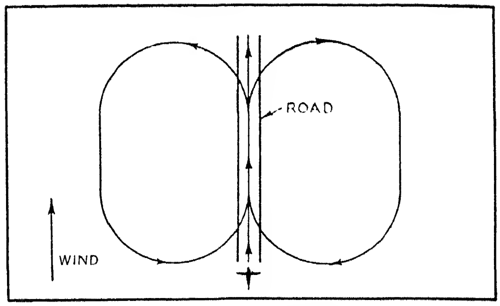


Fig. 2-39. Prob. 2-6.

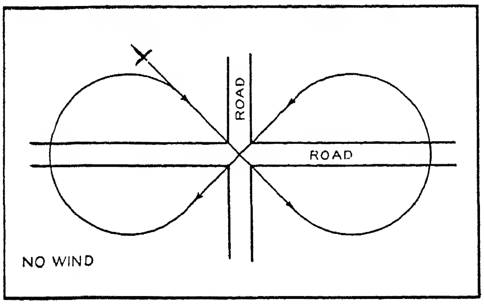


Fig. 2-40. Prob. 2-7.

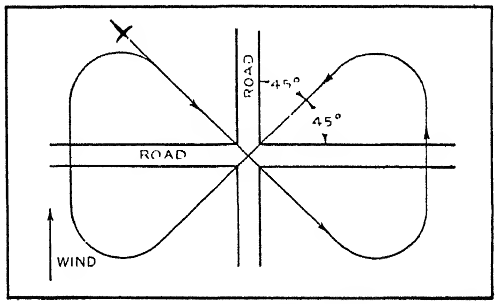


Fig. 2-41. Prob. 2-8.

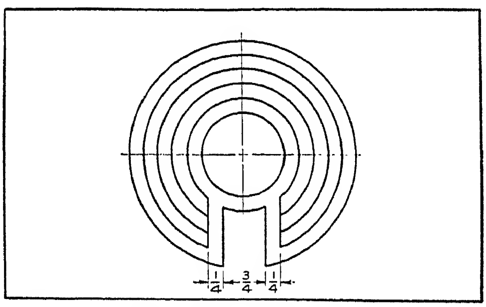


Fig. 2-42. Prob. 2-9.

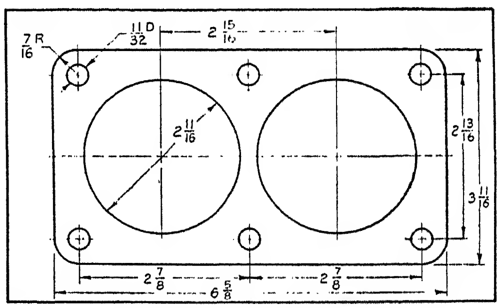


Fig. 2-43. Prob. 2-10.

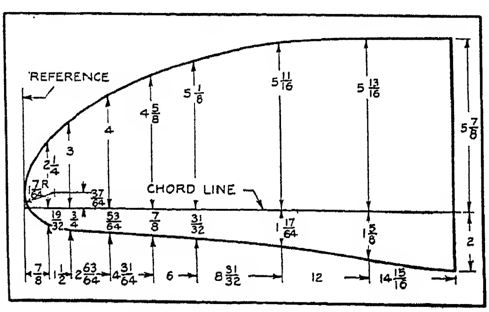


Fig. 2-44. Prob. 2-11.

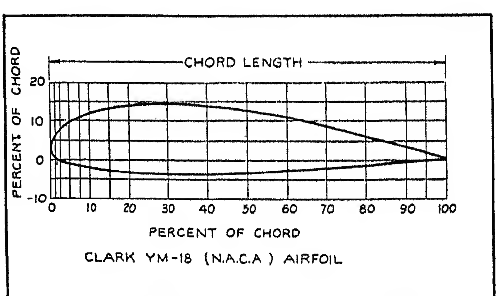


Fig. 2-45. Prob. 2-12.

Prob. 2–11. Fig. 2–44. — Plot and draw the curve shown. Refer to Art. 2–9. Draw the REFERENCE line 1/4 from left side of the space. Draw the CHORD, 1 5/8 above bottom of the space. Note that the horizontal distances are all measured from the vertical reference line to the arrow point.

Prob. 2–12. Fig. 2–45. — Plot and draw the airfoil shown. Draw the horizontal axis through the origin *O*. Select a suitable scale and lay off the per cent distances as indicated. Lay off the upper and lower values from the designated points of the horizontal axis. Use engineers' scale or scale with decimal divisions. Assume the chord length — in this case 6.7 inches. This chord length must be multiplied by the percentages given in the table to obtain the lengths of the ordinates (vertical distances) at the designated per cents of the chord length. The figures with a minus sign mean lower ordinates and are to be measured below the horizontal axis which passes through the origin *O*.

Per cent of Chord	Upper	Lower	Per cent of Chord	Upper	Lower	Per cent of Chord	Upper	Lower
0	3.50	3.50	15.0	13.52	−2.69	70	9.33	−1.98
1.25	6.40	0.98	20.0	14.41	−3.02	80	6.62	−1.40
2.50	7.85	0.11	30.0	14.85	−3.15	90	3.55	−0.75
5.00	9.78	−0.94	40.0	14.47	−3.07	95	1.89	−0.40
7.50	11.07	−1.59	50.0	13.34	−2.82	100	.15	−0.03
10 00	12.07	−2.05	60.0	11.61	−2.42			

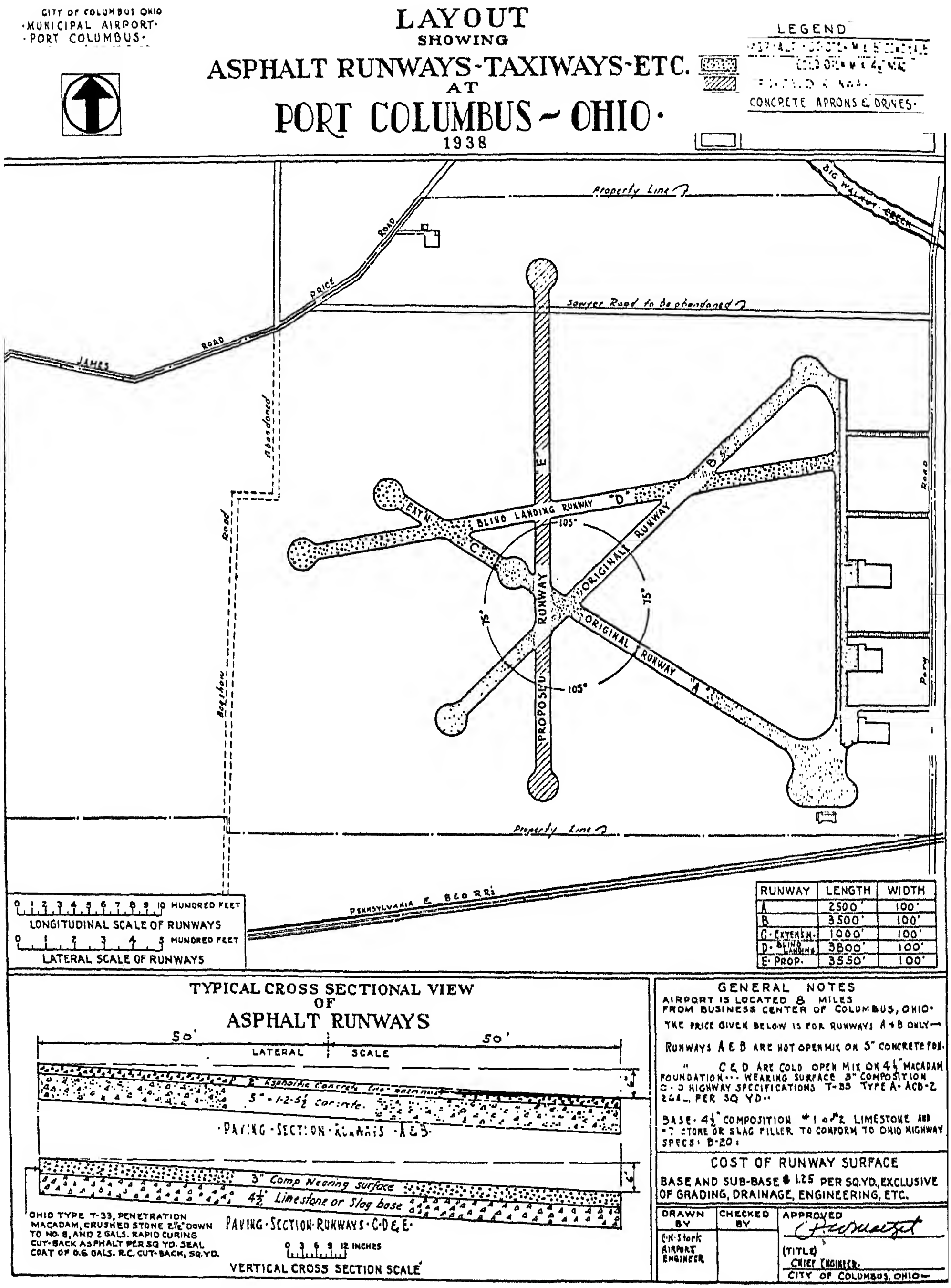


Fig. 3–1. Lines, Circles and Angles Applied. (*From the Asphalt Institute's Construction Series No. 4 "Asphalt for Airports".*)

CHAPTER III

BASIC GEOMETRICAL DRAWING

3–1. A working knowledge of basic geometrical constructions is essential in order to become expert in the use of straight lines, circles and the various curves which make up the views and diagrams in all phases of drawing in connection with the aircraft industry, whether design layouts, details and assemblies, graphic charts, or the necessary airport facilities (Fig. 3–1). The following articles include some reference material covering the most commonly used geometrical terms, figures and solids.

3–2. Points, Lines and Surfaces. — A point indicates position in space. When a point is moved it generates a line which may be either straight or curved A surface may be generated by moving a line. A plane surface is one which will

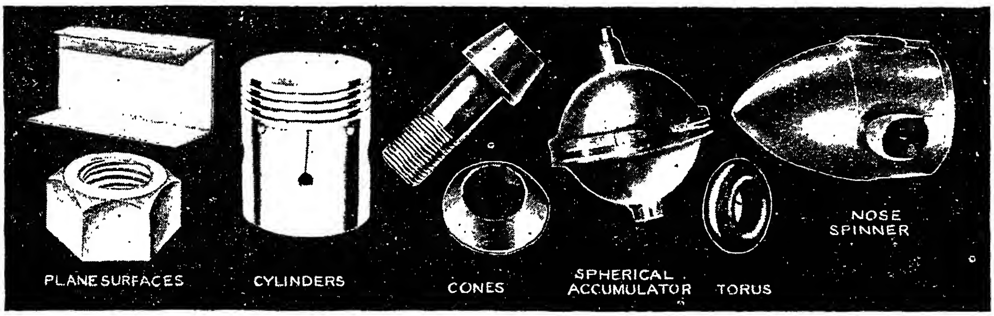


Fig. 3–2. Surfaces.

contain two intersecting straight lines or two parallel lines. Prisms have plane surfaces. Cylinders and cones have single curved surfaces. Spheres and such surfaces as direction finders and propeller nose spinners have double curved surfaces. Some surfaces are illustrated in Fig. 3–2.

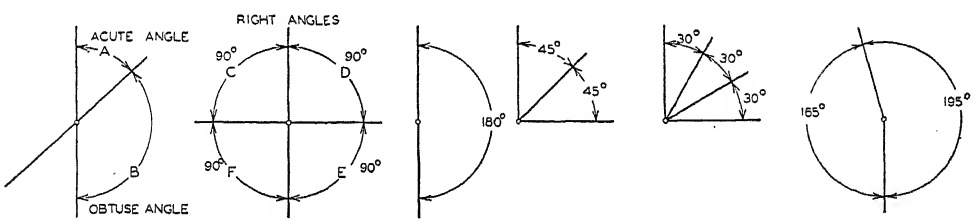


Fig. 3–3. Angles.

3–3. Angles. — When two straight lines intersect they form angles. The size of the angle is determined by the amount of opening between the lines. In

Fig. 3–3, angle A is less than angle B. If the lines make four equal angles, each angle is a *right* angle. Angles are measured in degrees, minutes and seconds. If a circle (of any size) is divided into 360 parts, each part represents one degree (°). A minute (′) is one-sixtieth of a degree and a second (″) is one-sixtieth of a minute.

A right angle (one-fourth of a circle) has one-fourth of 360° = 90°. A graduated circle or part circle in convenient form for measuring or laying out angles is called a protractor (Fig. 3–4). Angles may be worked out by scale drawings or computed, as for the *angle of drift* (Fig. 3–5).

3–4. A circle is a plane figure bounded by a curved line, all parts of which are equally distant from a fixed point. The curved line is called the circumference and the fixed point is called the center. Other features are illustrated in Fig. 3–6.

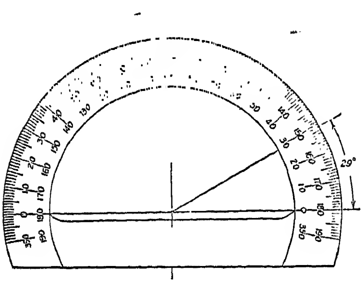


Fig. 3–4. Protractor.

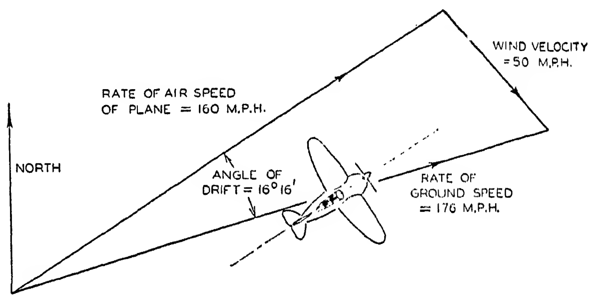


Fig. 3–5. Angle of Drift.

The circumference of a circle is equal to the diameter times 3.1416 (3.1416 is called Pi and is written π). The area of a circle is equal to $\pi/4$ times the diameter squared.

3–5. A triangle is a plane figure bounded by three straight lines (Fig. 3–7). The three angles in any triangle when added together are equal to 180° (two right angles). In a right triangle the sum of the squares of the two sides is equal to the square of the hypotenuse. Thus, in the figure $3^2 + 4^2 = 5^2$ or $9 + 16 = 25$.

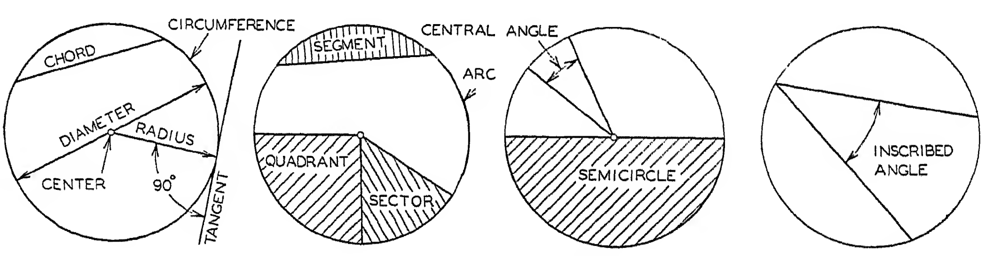


Fig. 3–6. The Circle.

3–6. A quadrilateral is a plane figure bounded by four straight lines (Fig. 3–8). Quadrilaterals are named as follows: trapezium — no two sides equal; trapezoid

— two sides, and only two, parallel; parallelogram — opposite sides parallel. The rhombus, rhomboid, square, and rectangle are parallelograms.

3–7. A polygon is a plane figure bounded by straight lines (Fig. 3–9). A *regular polygon* has equal angles and equal sides, and may be inscribed in, or circumscribed about, a circle.

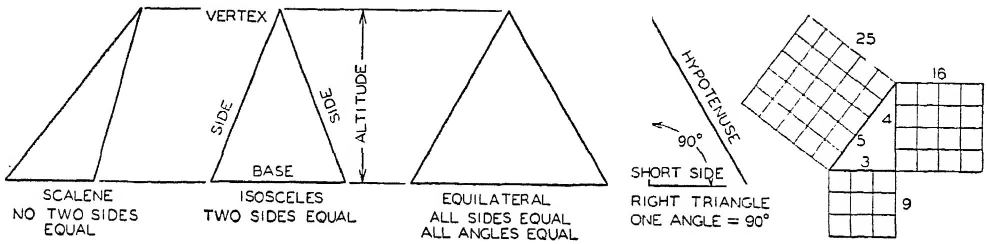


Fig. 3–7. Triangles.

3–8. Geometrical solids are illustrated and named in Fig. 3–10. There are five regular polyhedrons: The regular tetrahedron has four faces (equilateral triangles); the regular hexahedron or cube has six faces (squares); the regular

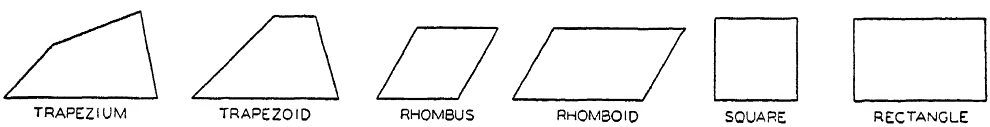


Fig. 3–8. Quadrilaterals.

octahedron has eight faces (equilateral triangles); the regular dodecahedron has twelve faces (regular pentagons); the regular icosahedron has twenty faces (equilateral triangles).

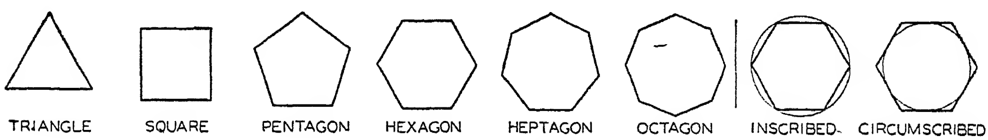


Fig. 3–9. Polygons.

3–9. Prisms (Fig. 3–10) are named according to the shape of the bases and the relation of the edges to the bases. A square prism has a square base, a triangular prism has a triangular base, etc. The vertical distance, *AB* (Fig. 3–10), between the bases is called the altitude. A section of a prism made by a plane perpendicular to the lateral edges is called a right section. A truncated prism has non-parallel bases. A parallelopiped is a prism with parallelograms for bases.

3–10. A pyramid (Fig. 3–10) is a polyhedron which has a polygon for one face, called the base, and a series of triangles having a common vertex for its other faces. A regular pyramid has a regular polygon for a base and the vertex on a perpendicular from the center of the base.

3–11. Cylinders. — A cylindrical surface (Fig. 3–10) is a single curved surface generated by a moving straight line having all its positions parallel, and guided by a curved line. A cylinder is a solid enclosed by a cylindrical surface and two parallel plane surfaces called bases. A circular cylinder has circles for bases.

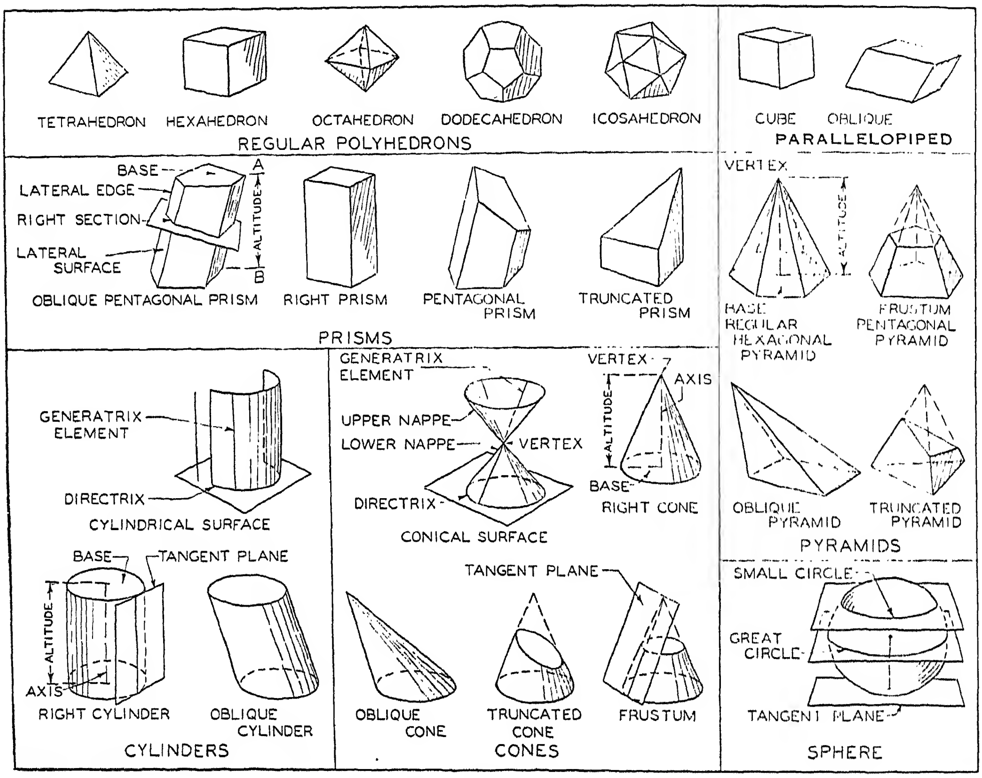


Fig. 3–10. Geometrical Solids.

3–12. Cones. — A conical surface (Fig. 3–10) is a single curved surface generated by a moving straight line which passes through a fixed point and is guided by a curved line. A cone is a solid enclosed by a conical surface and a plane surface called a base.

3–13. To Bisect a Line, an Arc or an Angle. — Given line or arc AB (Fig. 3–11), draw intersecting arcs with A and B as centers, and any radius greater than one-half AB. Draw CD the required bisector. It will be perpendicular (at right angles) to line AB. To Bisect angle AOB (Fig. 3–12). With O as a center

and any radius, draw an arc intersecting the sides of the angle at C and D. With C and D as centers and any radius greater than one-half CD draw arcs intersecting at E. The line OE bisects the angle.

3–14. To Divide a Line into a Number of Equal Parts. — Given the line AB, to divide it into five equal parts. *First method* (Fig. 3–13): Draw line AC at any convenient angle with AB. On AC, use any convenient setting of the dividers and step off five equal parts from A. Draw line $5B$ from point 5 and through points 4, 3, 2 and 1 draw lines parallel to $5B$. These will intersect the given line at points $4'$, $3'$, $2'$ and $1'$ and divide it into five equal parts. *Second method* (Fig. 3–14): Draw a perpendicular BC to given line AB, using triangle and T-square. Place a scale with one end of any five equal divisions at A and the other end on line BC. Mark opposite each division and draw verticals to AB.

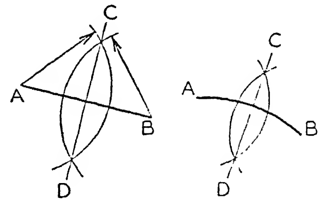


FIG. 3–11.

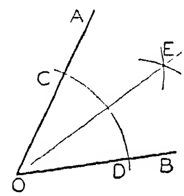


FIG. 3–12.

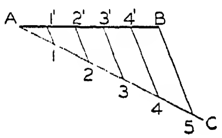


FIG. 3–13.

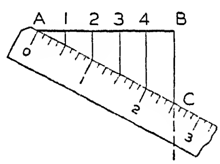


FIG. 3–14.

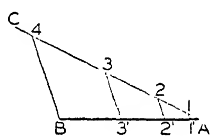


FIG. 3–15.

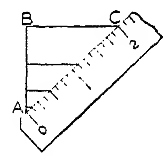


FIG. 3–16.

The intersections 1, 2, 3 and 4 divide AB into five equal parts. A *third method* makes use of the dividers as described in Art. 2–11.

3–15. To Divide a Line into Proportional Parts. — Given the line AB, to divide it into parts proportional to 1, 3, 5 and 7. *First method* (Fig. 3–15): Draw line AC at any convenient angle with AB. Lay off any convenient distance from A to 1. Make 1–2 equal to three times $A1$, 2–3 equal to five times $A1$ and 3–4 equal to seven times $A1$. A convenient way of doing this is to use a scale. Since the sum of 1, 3, 5 and 7 is 16, place a scale along AC and mark point 4 at the end of any sixteen divisions from point A. Mark one division from A to point 1, three divisions from 1 to 2, five from 2 to 3, and seven from 3 to 4. Lines parallel to $B4$ through points 1, 2 and 3 will divide line AB into parts proportional to 1, 3, 5 and 7. *Second method* (Fig. 3–16): Through B draw a

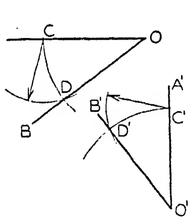


FIG. 3–17.

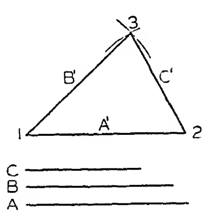


FIG. 3–18.

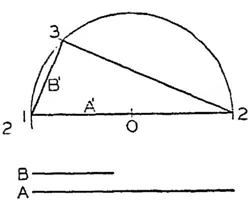


FIG. 3–19.

3–23. To Draw a Circle Passing Through Any Three Points. — Given three points A, B and C (Fig. 3–31), join the points to form a triangle. Bisect any two sides as AB and BC by perpendiculars intersecting at the center, O. The radius of the required circle is OA. To find the center of a circle or arc, assume three points on the circle or arc and proceed as above.

3–24. To Draw a Tangent to a Circle at a Given Point. — Place a triangle with its hypotenuse passing through the given point T and the center of the circle as indicated in the first position (Fig. 3–32). Use another triangle or the T-square as a base, turn the first triangle through 90° into the second position, and move it along the base until its hypotenuse passes through T. Draw the tangent TA. The base must be held firmly in place.

3–25. To Find the Length of a Given Arc of a Circle and Lay It Off on a Given Straight Line. — This is called rectifying the arc. *First method* (Fig. 3–33), when angle AOB is less than 60°: At one end of the given arc AB draw the

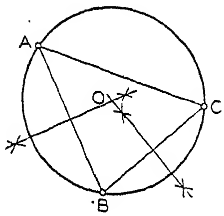


Fig. 3–31.

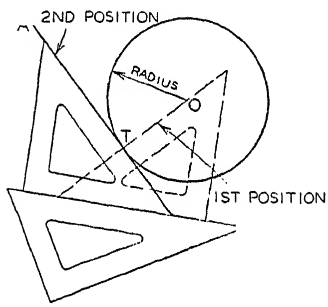


Fig. 3–32.

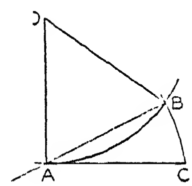


Fig. 3–33.

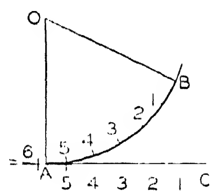


Fig. 3–34.

tangent AC. Draw the chord AB and produce it to D making DA equal to one-half chord AB. With D as a center and radius DB draw arc BC. Line AC will be approximately equal in length to arc AB. *Second method* (Fig. 3–34), for any angle and for any curves including circles: Draw the tangent AC. Set the bow dividers to some small distance. Start at point B and step off points 1, 2, 3, etc., along the arc until a point comes near to A. Do not remove the dividers but step back along the line AC, the same number of spaces, as shown. By taking small spaces the chords may be assumed equal to the arcs.

3–26. To Draw a Reversed or Ogee Curve. — Given parallel lines AB and CD and point T on line BC (Fig. 3–35): To draw the required curve, arcs are drawn tangent to AB and CD at B and C and to each other at the point T. Erect perpendiculars at B and C and draw the perpendicular bisectors of BT and TC. The intersections of these perpendiculars at points 1 and 2 will be the centers of the required arcs with radii $1B$ and $2C$ which are tangent at point T on line of centers 1–2.

3–27. To Draw an Arc of a Circle Tangent to Two Given Lines. — Given the lines AB and BC, and radius R (Figs. 3–36 and 3–37), draw DE parallel to

BC at a distance equal to R. Draw FG parallel to AB and at a distance equal to R. Point O the intersection of FG and DE is the center of the required arc. Perpendiculars to AB and BC through O will locate the points of tangency. When angle ABC is a right angle (Fig. 3–38) locate points 1 and 2 by drawing an arc with radius R and center B. Locate point O by drawing arcs with radius R and centers 1 and 2.

3–28. The Involute. — A curve which is the locus of a point on a cord as it unwinds from a polygon of any number of sides is called an involute. When the number of sides is infinite the involute of a circle is obtained. By reducing the two opposite sides of a rectangle to practically zero, the involute of a right line is obtained.

3–29. To Draw the Involute of a Triangle or Square. — Given the triangle ABC (Fig. 3–39), with A as a center, and AC as a radius, draw an arc to intersect AB produced at 1. With B as a center and $B1$ as a radius, draw an arc to intersect CB produced at 2, etc. The curve may be continued indefinitely by increasing each succeeding radius as above. The involute of a square is drawn in like manner (Fig. 3–40), using the corners of the square as centers.

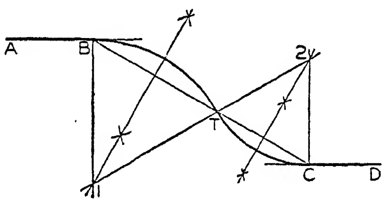


FIG. 3–35.

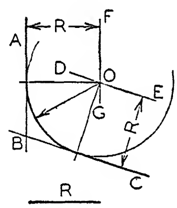


FIG. 3–36.

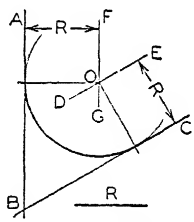


FIG. 3–37.

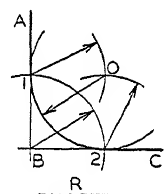


FIG. 3–38.

3–30. To Draw the Involute of a Circle. — Given the circle (Fig. 3–41), divide the circumference into a sufficient number of equal parts, using 15° intervals for convenience, and draw radial lines OA, OB, etc. Draw tangents at A, B, C, etc., as shown. Starting at A, lay off the distance $A1$ on the tangent equal to the arc AP by the method of Fig. 3–34. From B lay off $B2$ on the tangent equal to arc BAP. Continue to lay off on each tangent a distance from the point of tangency equal to the arc of the circle, measured from the point of tangency to the point P. Draw a smooth curve from P through points 1, 2, 3, etc. If the complete circumference is used the complete involute of the circle will be obtained. The involute has a practical application in the formation of cut gears. Most modern gears have teeth based on the involute system.

3–31. The Helix. — A cylindrical helix is a curve generated on the surface of a revolving cylinder by a point which moves uniformly parallel to the axis of the cylinder as the latter revolves uniformly. The helix is the basis of all screw thread design. The blade tips of a propeller move in the path of a helix — they revolve as they travel forward — and from this the term air screw has been applied to the propeller. The *pitch* of the helix is the distance through which

the point moves parallel to the axis for one revolution of the cylinder. For a propeller the pitch is the distance it would travel through " solid " air. The distance is, of course, less in the air and this *slip* is taken care of by an increase in the pitch.

3–32. To Draw the Projections of a Cylindrical Helix. — Let D be the diameter and p the pitch of a cylinder as indicated in Fig. 3–42. Divide the circle into any convenient number of equal angular parts 1, 2, 3, etc., and draw horizontal lines through each point. Divide the pitch into the same number of equal linear parts and draw vertical lines through each point. For each linear space, which the point moves parallel to the axis of the cylinder the latter will revolve through one angular space. The intersection of a vertical line from a division of the pitch with a horizontal line from the corresponding division of the circle will locate a point on the projection of the helix. Proceed in this way for each of the remaining points. It is advisable to locate intermediate points on half divisions where the curve changes direction as at point 7.

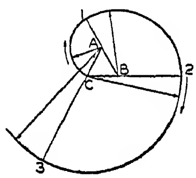


Fig. 3–39.

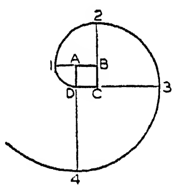


Fig. 3–40.

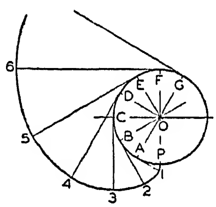


Fig. 3–41.

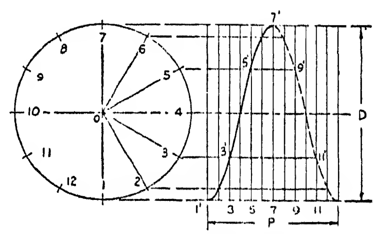


Fig. 3–42. The Helix.

3–33. The Ellipse — Definition. — The ellipse (Fig. 3–43) is a plane curve which is the locus of a point moving so that the sum of its distances (*focal radii*) from two fixed points (*foci*) in the plane is a constant (equal to the *major axis*). The major axis AB is the long diameter and the *minor axis* CD is the short diameter. Given the major and minor axes of an ellipse, the foci F_1 and F_2 can be located on the major axis by drawing an arc with C or D as a center and a radius equal to one-half the major axis.

A *normal* PG to an ellipse through any point P on the curve is the bisector of the angle F_1PF_2 formed by connecting the foci with the point. A *tangent* PE to an ellipse at any point P is perpendicular to the normal through that point.

3–34. To Draw an Ellipse by the Locus Method. — Given the foci F_1 and F_2, and major axis AB (Fig. 3–43). With AO as a radius and F_1 and F_2 as centers, draw arcs (not shown) intersecting at C and D to determine the minor axis. With F_1 as a center and any radius R_1 less than F_1B, draw a small arc. With F_2 as a center and a radius R_2 equal to AB minus R_1, draw another arc intersecting the first arc at points P and P' to obtain points on the required ellipse. Locate other points by using similar pairs of radii with F_1 and F_2 as centers. In each case the sum of the two radii must be equal to the major axis. If the major and minor axes are given locate the foci and proceed as above.

3–35. To Draw an Ellipse by the Concentric Circle Method. — With O as a center (Fig. 3–44), draw circles having the major and minor axes as diameters. Draw radial lines OeE, OfF, etc., at convenient intervals, say 15°. From points E, F, G, etc., draw lines perpendicular to the major axis. From points e, f, g, etc., draw lines parallel to the major axis. The intersection of perpendicular and parallel lines from points on the same radial line will determine a point on the ellipse as indicated at 1, 2, 3, etc. Find a sufficient number of points and sketch a freehand curve very lightly through them. Select a suitable irregular curve and draw a smooth heavy line.

3–36. False Ellipses. — Approximate curves may be drawn with circular arcs which resemble ellipses in appearance. They may be used for some purposes where the mathematical properties of true ellipses are not essential.

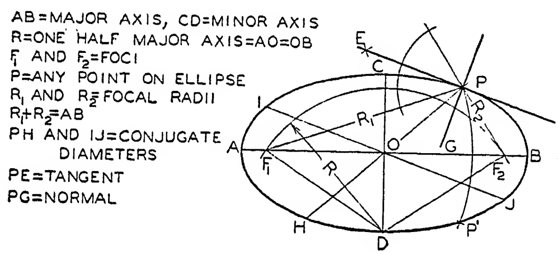


Fig. 3–43. The Ellipse.

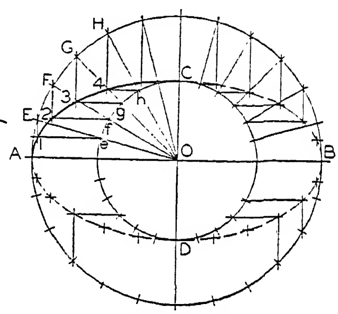


Fig. 3–44. Concentric Circle Method.

A common approximation is shown in Fig. 3–45 when the minor axis is equal to or greater than two-thirds of the major axis. Lay off $O1$ and $O2$, each equal to the difference between the major and minor axes. Lay off $O3$ and $O4$ equal to three-fourths of $O1$. Draw arcs with centers 1 and 2 and radius $1D$ to meet arcs drawn from centers 3 and 4 with radius $3B$.

In Fig. 3–46, lay off AE equal to CD. Lay off OF and OG each equal to two-thirds of EB. With center F and radius FG draw arc to locate H. Draw arcs with centers F and H and radii FB and HC.

3–37. The Parabola — Definition. — The parabola (Fig. 3–47) is a plane curve which is the locus of a point moving so that its distance from a fixed point F, called the focus, is always the same as its distance from a fixed line CD, called the *directrix*. A line through the focus perpendicular to the directrix is called the *axis*. The intersection of the curve with the axis is called the *vertex*.

A *tangent* TP to a parabola at any point P on the curve is the bisector of the angle formed by the radial line FP and the perpendicular PC to the directrix. The normal PM is perpendicular to the tangent PT.

3–38. To Draw a Parabola by the Locus Method. — Given the directrix CAD and focus F (Fig. 3–47), draw a line parallel to the directrix, at any distance (see 1) from it. Use this distance as a radius and w

cut the parallel line at 1. Draw a sufficient number of such parallels and in like manner locate other points on the required parabola. The vertex O is, of course, midway between A and F.

3–39. To Draw a Parabola by the Parallelogram Method. — Given the parallelogram $CDEF$ (Fig. 3–48), divide BF and CF into the same number of equal parts. Draw lines from A to each point on CF and from each point on BF parallel to AB. Points on the required curve are located by the intersections of the pairs of lines as shown.

When the axis (AB) is inclined to a base (FE) the same construction may be used as indicated in Fig. 3–49.

3–40. The Hyperbola — Definition. — The hyperbola (Fig. 3–50) is a plane curve which is the locus of a point moving so that the difference of its distances from two fixed points (*foci*) is a constant and equal to the *transverse axis* AB.

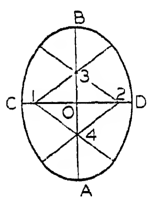


Fig. 3–45.

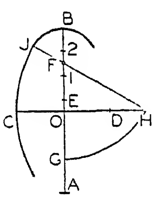


Fig. 3–46.

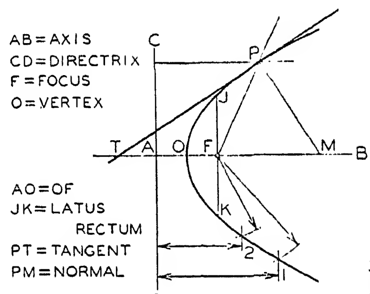


Fig. 3–47. The Parabola.

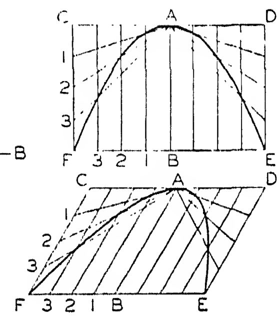


Fig. 3–48. (*Above*)
Fig. 3–49. (*Below*)

A tangent to a hyperbola at any point 1 is the bisector of the angle formed by the focal radii $F_1 1$ and $F_2 1$.

A hyperbola which has CD for its transverse axis is called the conjugate hyperbola. The conjugate axis CD is perpendicular to AB at its mid-point O. Arcs drawn with centers A and B and radius equal to one-half the distance between the foci (OF_1 or OF_2) will intersect at C and D the extremities of the conjugate axis.

The diagonals (produced) of a rectangle formed by the tangents to the hyperbolas at A, B, C and D are called asymptotes.

3–41. To Draw a Hyperbola by the Locus Method. — Given the foci and transverse axis AB (Fig. 3–50), with any radius $F_1 1$ greater than $F_1 B$, and centers F_1 and F_2, draw short arcs at 1. With radius equal to $F_1 1$ minus AB and centers F_1 and F_2 draw short arcs intersecting the first arcs at the points marked 1. To locate additional points 2, 3, etc., proceed in the same way, subtracting AB from increasing radii $F_1 2$, $F_1 3$, etc., for each point.

3-42. To Draw a Hyperbola by the Parallelogram Method. — Given the transverse axis *AB* and double ordinate *EF* (Fig. 3-51), draw a parallelogram *CDEF* and divide *GF* and *CF* into the same number of equal parts. Draw lines from *A* to each point on *GF* and from *B* to each point on *CF*. Points on the required curve are located by the intersections of pairs of lines as shown.

3-43. The Equilateral Hyperbola. — When the transverse and conjugate axes are equal and at right angles to each other the curve is called an equilateral or rectangular hyperbola.

This curve is used in connection with the study of steam and gas engine indicator diagrams. It represents the expansion of a perfect gas, with p = absolute pressure, v = volume, and pv = a constant. When thus applied, the asymptotes are drawn in a horizontal and vertical position (Fig. 3-52). Given point *P* and asymptotes *OS* and *OS'*, through *P* draw lines *PE* and *PG* parallel to *OS* and *OS'*. Draw radial lines from *O* intersecting *PE* and *PG* in points 1, 2, 3 . . . From corresponding intersections draw horizontal and vertical lines which intersect, to locate points on the hyperbola.

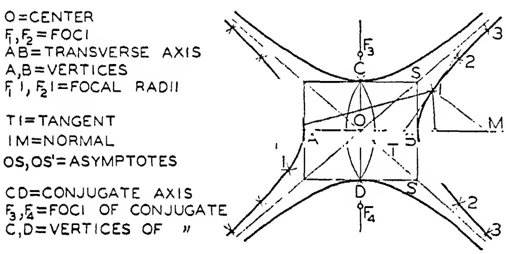


FIG. 3-50. The Hyperbola.

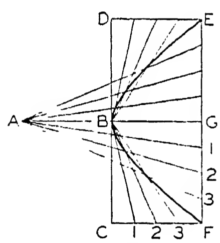


FIG. 3-51.

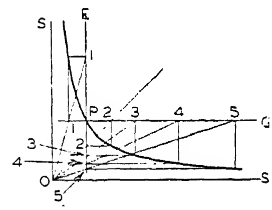


FIG. 3-52. Equilateral Hyperbola.

3-44. PROBLEMS. — A knowledge of certain basic geometrical constructions is necessary in order to gain speed in laying out and understanding aircraft drawings. Selections from the problems which follow should be solved by the methods given in this Chapter. Do not copy the figures but learn the principles and apply them to the solution of each problem. Each problem can be solved in one quarter of a four-part layout (Fig. 2-31). Use a sharp pencil and work accurately.

Group 1. Straight Lines.

Prob. 3-1. Fig. 3-53. — Bisect a straight line. Draw a very light straight line about 4 long. *Assume this length, do not measure it.* Lay off points $3\frac{5}{16}$ apart and with these points as centers draw arcs and draw the bisector as explained in Art. 3-13, Fig. 3-11.

Prob. 3-2. Fig. 3-54. — Divide a line into a number of equal parts. Draw a horizontal line $3\frac{7}{16}$ long located $1\frac{1}{4}$ below the top of the space. Divide the line into five equal parts as explained in Art. 3-14, Fig. 3-13.

Prob. 3-3. Fig. 3-55. — Copy an angle. Draw a vertical line $\frac{1}{2}$ to the right of the left side of the space. Draw another line making any convenient angle with it. Copy this angle so that one side will be $\frac{1}{2}$ below the top of the space. Refer to Art. 3-16.

Prob. 3-4. Fig. 3-56. — Draw a triangle having sides as follows: $A = 3\frac{7}{8}$; $B = 5\frac{7}{16}$; $C = 2\frac{1}{2}$. Refer to Art. 3-17.

Prob. 3-5. Draw one of the following equilateral triangles: No. 1, Side = $3\frac{9}{16}$. No. 2, Side = 4. No. 3, Side = $3\frac{5}{16}$.

Prob. 3-6. Draw one of the following isosceles triangles: No. 1, Base = $5\frac{1}{4}$, Side = $4\frac{3}{8}$. No. 2, Base = $2\frac{5}{8}$, Side = $3\frac{1}{4}$.

Prob. 3-7. Draw one of the following right triangles: No. 1, Hypotenuse $4\frac{5}{8}$, One angle 60°. No. 2, Hypotenuse $6\frac{1}{4}$, One side = $3\frac{3}{4}$.

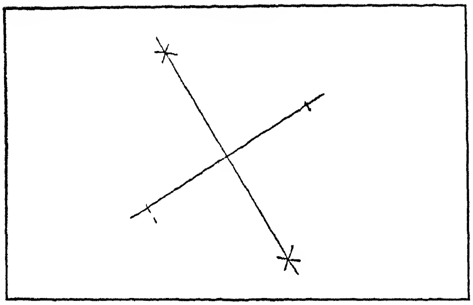


FIG. 3-53. Prob. 3-1.

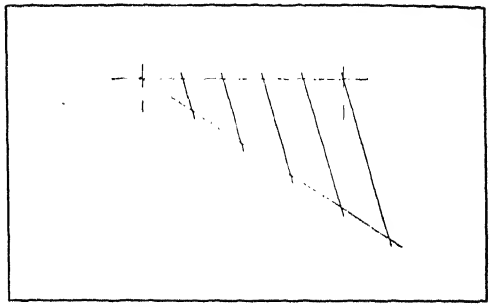


FIG. 3-54. Prob. 3-2.

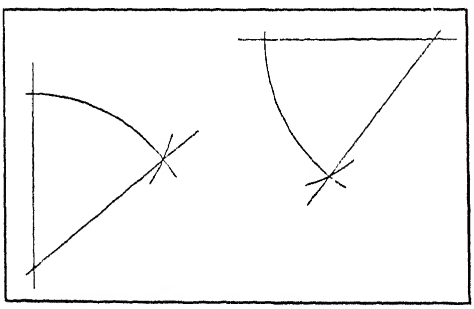


FIG. 3-55. Prob. 3-3.

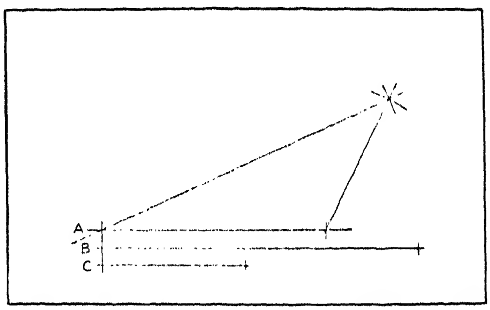


FIG. 3-56. Prob. 3-4.

Solve **Probs. 3-8, 3-9, and 3-10** with 30°-60° and 45° triangles, T-square, scale, and compasses.

Prob. 3-8. Fig. 3-57. — Draw the plate as shown.

Prob. 3-9. Fig. 3-57. — The plate shown is LEFT-HAND. Draw a RIGHT-HAND plate.

Prob. 3-10. Fig. 3-58. — Draw the plate shown in Fig. 3-57, but with the line AB in the position indicated in Fig. 3-58.

Group 2. Polygons.

Probs. 3-11 to 3-14. Draw a regular hexagon. Prob. 3-11, in a circle of $3\frac{7}{16}$ diameter. Prob. 3-12, Flats, $3\frac{1}{8}$. Prob. 3-13, Corners, $4\frac{3}{16}$. Prob. 3-14, One side = $2\frac{3}{16}$.

Prob. 3-15. Draw a regular pentagon in a circle of $3\frac{11}{16}$ diameter.

Prob. 3-16. Draw a regular octagon in a $3\frac{7}{16}$ square

Prob. 3-17. Fig. 3-59. — Draw one or more of the figures illustrated. Diameter of circle = $3\frac{3}{4}$.

Group 3. Circles and Tangents.

Prob. 3-18. Mark three points A, B and C, not in a straight line. Draw a circle passing through these points. Refer to Fig. 3-31.

Prob. 3-19. Draw a circle with a diameter of 3¼. Mark any two points on the circumference and draw tangents by method of Art. 3-24.

Prob. 3-20. Draw an arc of 45° with a radius of 3. Find the length of the arc by the first method of Art. 3-25. Measure the result and check by computation.

Prob. 3-21. Same as Prob. 3-20 by the *second method* of Art. 3-25.

Prob. 3-22. Draw angles of 120°, 60° and 90° and draw tangent arcs with radius of ⅞. Refer to Figs. 3-36, 3-37 and 3-38.

Prob. 3-23. Fig. 3-60.—Draw the OFFSET PIPE BEND. Center line is composed of tangent arcs with equal radii. Scale 1½″ = 1′-0″. Refer to Fig. 3-35.

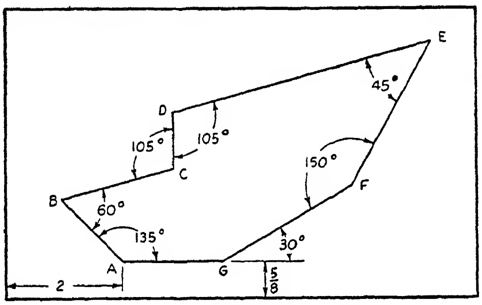


FIG. 3-57. Probs. 3-8 and 3-9.

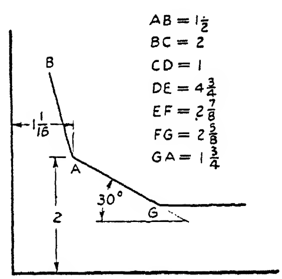


FIG. 3-58. Prob. 3-10.

Prob. 3-24. Fig. 3-61. — Draw the METER FACE. Diameter of plate is 9. Arcs of upper opening have center 4 below center of face with radii of 5½ and 7 respectively. Small arcs have radius of ⅜. The large arcs of lower opening have a radius of 3⅝, one center 2 above and other 4 below center of face. The small arcs have a ⅜ radius. Scale: Full size for 11 × 17 sheet and half size for 5 × 8¼ space.

Prob. 3-25. Fig. 3-62. — Draw the Y-PLATE as shown and indicate all tangent points.

Prob. 3-26. Fig. 3-63. — Draw the SHIM.

Prob. 3-27. Fig. 3-64. — Draw the GASKET.

Group 4. Involute, Conic Sections, etc.

Prob. 3-28. Draw an involute of a triangle, side AC = ⅝, Fig. 3-39.

Prob. 3-29. Draw an involute of a square, side AD = ¾, Fig. 3-40.

Prob. 3-30. Draw an involute of a circle, diameter = 1½. Refer to Fig. 3-41.

Prob. 3-31. Draw one complete turn of a helix. Diameter = 3½. Pitch = 2¼. Refer to Fig. 3-42.

Prob. 3-32. Draw an ellipse by the locus method (Art. 3-34). Major axis = 5. Minor axis = 3.

Prob. 3-33. Draw an ellipse by the concentric circle method (Art. 3-35). Find 24 points. Major axis = 4½. Minor axis = 2.

Prob. 3-34. Draw an approximate ellipse by method of Fig. 3-45. Major axis = 4½. Minor axis = 3¼.

Prob. 3-35. Draw an approximate ellipse by method of Fig. 3-46. Major axis = 5. Minor axis = 2.

Prob. 3-36. Draw a parabola by method of Fig. 3-47. Directrix is vertical and focus is 1¼ to the right.

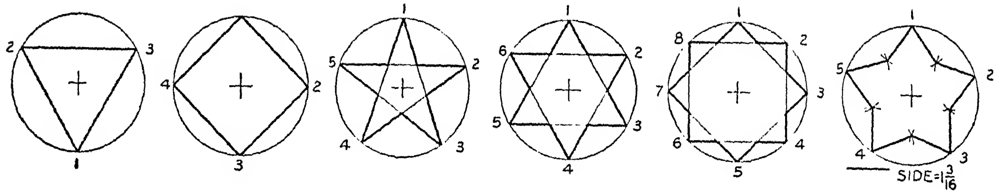


Fig. 3-59. Prob. 3-17.

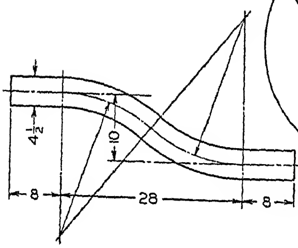


Fig. 3-60. Prob. 3-23.

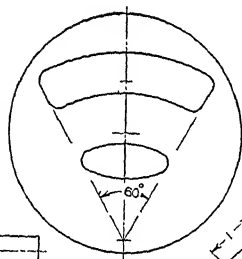


Fig. 3-61. Prob. 3-24.

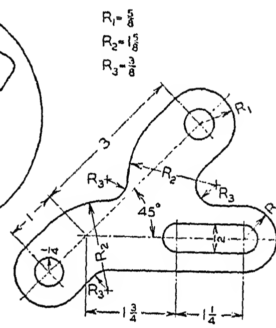
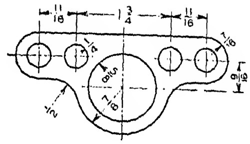


Fig. 3-62. Prob. 3-25.



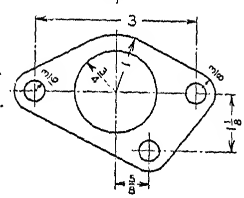


Fig. 3-63. Prob. 3-26 (*Above*)
Fig. 3-64. Prob. 3-27 (*Below*)

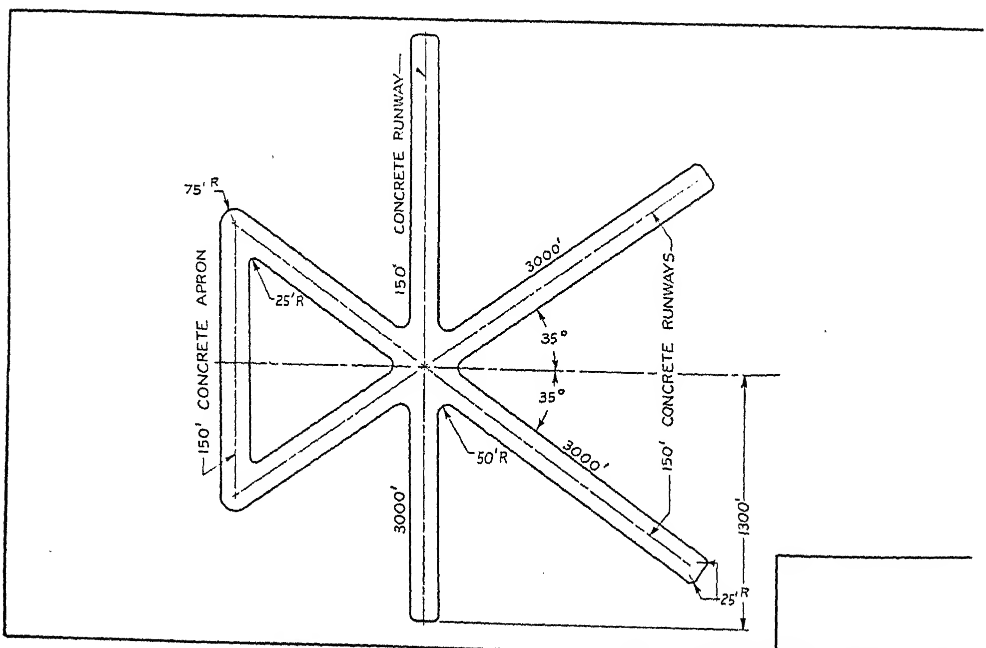


Fig. 3-65. Prob. 3-42.

Prob. 3–37. Draw a parabola by method of Fig. 3–48. Make $CF = 3\frac{1}{4}$ and $FE = 6\frac{1}{4}$.

Prob. 3–38. Draw a parabola by method of Fig. 3–49. Make $CF = 3$ and $FE = 5$. Axis makes angle of 30° with horizontal.

Prob. 3–39. Draw an hyperbola by method of Art. 3–40. Transverse axis $1\frac{3}{4}$. Distance between foci $= 2\frac{1}{4}$.

Prob. 3–40. Draw an hyperbola in a rectangle, $4\frac{1}{2}$ wide and $2\frac{1}{4}$ high, axis vertical. Refer to Art. 3–42.

Prob. 3–41. Draw an equilateral hyperbola through point P (Fig. 3–52) located 3 above OS' and $\frac{3}{4}$ to the right of OS.

Prob. 3–42. Fig. 3–65. — Make a layout drawing for the airport. An aerial photograph of this airport is shown in Fig. 2–2. Scale: 1 inch = 500 ft.

Prob. 3–43. Fig. 3–1. — Make a layout drawing for the airport.

CHAPTER IV

STANDARD LETTERING

4–1. Aircraft lettering practice is chiefly concerned with legibility. Plain, easily read letters which can be made rapidly have, therefore, become standard practice for use on aircraft drawings for notes and figures to give information as to size, location of parts, accuracy required, material, kinds of finish, methods of assembling, number required and identity of parts.

The proportions and forms of letters are not fixed by an exact standard but good practice does not permit much variation in engineering lettering.

The appearance of letters may be changed by using compressed or extended letters, Fig. 4–1, or by using light face or bold face letters, Fig. 4–2.

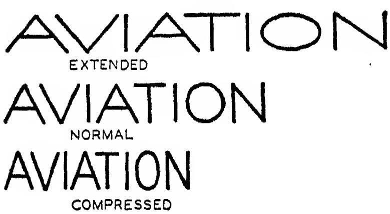


Fig. 4–1. Extended and Compressed Letters.

Fig. 4–2. Light Face and Bold Face Letters.

4–2. Pencil letters are made with an H (or softer) pencil sharpened to a long conical point. To maintain even lines, form the habit of turning the pencil in the fingers after every letter. Light lines to limit the height of the letters should always be drawn (except possibly on preliminary design drawings and layouts). Such guide lines may be spaced off with the bow dividers and drawn with the T-square or triangle, or more conveniently with the Braddock-Rowe triangle or the Ames lettering instrument (Figs. 4–3 and 4–4). When using, the device is placed against a straight-edge and a sharp pencil inserted successively in each hole of the group selected for the desired height of letters, and guide lines are drawn as the device is moved along the straight-edge. A slight pressure of the pencil point against the side of the hole will maintain sliding contact. The heights of capital letters in thirty-seconds of an inch are given by the numbers. Thus, 3 means $\frac{3}{32}$ inch high, 4 means $\frac{4}{32}$ inch or $\frac{1}{8}$ inch high, etc.

4–3. Single-stroke letters are standard for most engineering purposes. They are made up of uniform width lines or *strokes* as formed by the pencil or pen point. Such letters are often called single-stroke commercial gothic letters. Capital letters are used on aviation drawings, either vertical or inclined according

to the company preference. All lettering notes and figures are *placed on the drawing so as to read from the bottom of the sheet regardless of the positions of the dimension lines*, on most aircraft drawings. Aircraft engine manufacturers and some other companies follow general engineering practice and place dimensions to read " in line " with the dimension line, from the lower or right-hand sides of the sheet.

Regular notes and numbers for dimensions are made ⅛ inch to 5/32 inch high, titles about 3/16 inch high and fraction numbers three-fourths the height of regular numbers.

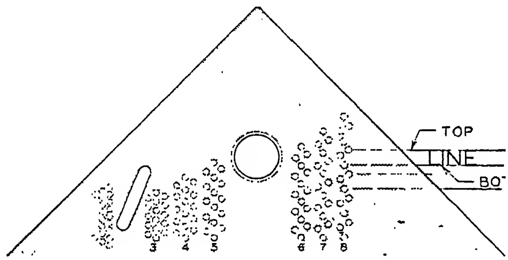


FIG. 4–3. Braddock-Rowe Triangle.

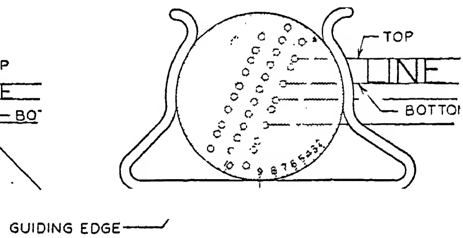


FIG. 4–4. Ames Lettering Instrument.

Single-stroke letters are shown in Figs. 4–5 and 4–6, which are reproduced from " American Standards Drawings and Drafting Room Practice " of the American Standards Association (ASA — Z14.1), from which the following is quoted.

" The most important requirement for lettering as used on working drawings is legibility, the second is ease and rapidity of execution. These two requirements are met in the single-stroke commercial gothic letter, now in almost universal use throughout the technical world. Preference seems to be divided between the vertical and the inclined styles.

" The following standard practice is recommended:

" a. That single stroke commercial gothic lettering either vertical or inclined at a slope of 2 in 5 be used on all working drawings for titles, notes, etc.

" b. That only capitals be used in the title box.

" c. That for notes, bill of material, etc., if the vertical style is chosen the letters should be all capitals. If the inclined style is chosen the letters may be all capitals or capitals and lower-case.

" It is not desirable to grade the size of lettering with the size of drawing except when a reduced photographic reproduction of the drawing is to be made. In other words the size and weight of the lettering should be such as will produce legible prints from tracings either in pencil or in ink.

" Lettering should not be underlined except for particular emphasis." (On aircraft drawings it is general practice to underline notes).

The lower case or small letters shown as type 6 in Fig. 4–6 are used on many engineering drawings but not on aviation drawings.

4–4. The lettering shown in Fig. 4–7 is from the Lockheed Aviation Corporation Drafting Room Manual. Single-stroke commercial gothic capitals are specified, either slant or vertical, ⅛ inch high. Title letters, 3/16 inch high; sec-

TYPE 1 ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$
TITLES & DRAWING NUMBERS

TYPE 2
FOR SUB-TITLES OR MAIN TITLES
ON SMALL DRAWINGS

TYPE 3 ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{9}{3}$
FOR HEADINGS AND PROMINENT NOTES

YPE 4 ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{23}{64}$
FOR BILLS OF MATERIAL, DIMENSIONS & GENERAL NOTES

TYPE 5
Optional Type same as Type 4 but using Type 3 for First Letter of Principal Words. May be used for Sub-titles and Notes on the Body of Drawings.

FIG. 4-5. Vertical Single-Stroke Letters. (*American Standard.*)

tion letters, ¼ inch high; numerals, ⅛ inch high including upper and lower figures of the fractions. A horizontal bar is used in fractions. Numerals for tolerance notes are made $\frac{3}{32}$ inch high.

The outline modern roman letters are used for cutting planes, and point of view indications as for enlarged views (Fig. 4-8).

4-5. Letter Spacing. — The general rule for spacing letters in words is to have the *areas* between letters appear to be about equal. Such letters as *A* and *T*, *A* and *V*, *L* and *A*, etc., should be placed closer together than round letters like *O* and *C* Such letters as *H*, *I*, *N*, etc., should be placed further apart. The reason for care in spacing letters is to have each word appear as a unit (compare the words in Fig. 4-9).

4-6. Titles are a necessary part of every aircraft drawing and should follow the AN Standards of the Army and Navy. Title blocks are shown on Figs. 7-1 and 9-4, and many other drawings in this book. They indicate the information which is required as: Scale of drawing, part number, name of part, assembly

TYPE 1 ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{7}{16}$
TO BE USED FOR MAIN TITLES
& DRAWING NUMBERS

TYPE 2 ABCDEFGHIJKLMNOPQR
STUVWXYZ&
1234567890 $\frac{13}{64}$ $\frac{5}{8}$ $\frac{1}{2}$
TO BE USED FOR SUB-TITLES

TYPE 3 ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{7}{16}$
FOR HEADINGS AND PROMINENT NOTES

TYPE 4 ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{1}{4}$ $\frac{3}{8}$ $\frac{5}{16}$ $\frac{7}{32}$ $\frac{1}{8}$
FOR BILLS OF MATERIAL, DIMENSIONS & GENERAL NOTES

TYPE 5
OPTIONAL TYPE SAME AS TYPE 4 BUT USING TYPE 3 FOR FIRST LETTER OF PRINCIPAL WORDS. MAY BE USED FOR SUB-TITLES & NOTES ON THE BODY OF DRAWINGS.

TYPE 6 abcdefghijklmnopqrstuvwxyz
Type 6 may be used in place of
Type 4 with capitals of Type 3,
for Bills of Material and Notes
on Body of Drawing.

FIG. 4-6. Inclined Single-Stroke Letters. (*American Standard.*)

number, material, stock, number required, unit weight, finish, heat treatment, left- or right-hand views, scale of drawing, changes, and names or initials of draftsman, engineer, etc.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{7}{16}$ $\frac{21}{32}$ *1 2 3 4 5 6 7 8 9 0* $\frac{1}{2}$ $\frac{3}{4}$ $\frac{7}{16}$ $\frac{21}{32}$

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

FIG. 4–7. From "Lockheed" Manual.

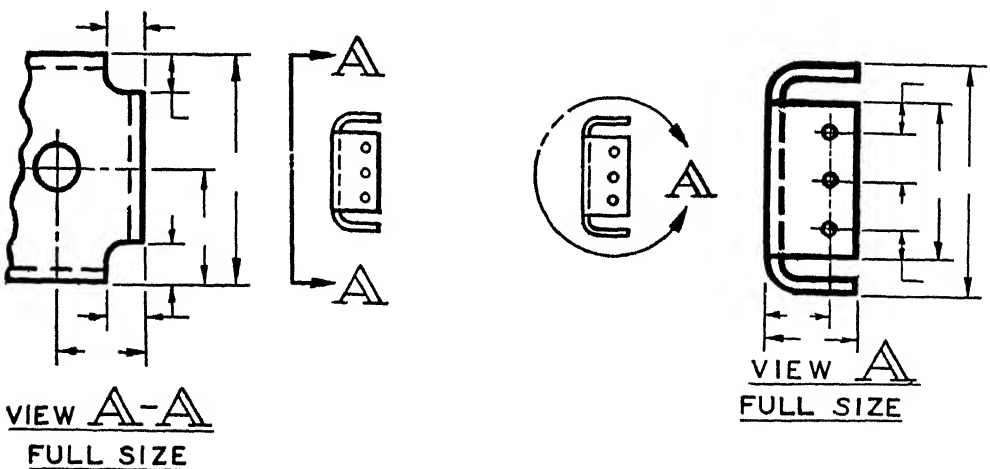


FIG. 4–8. Letters from Fig. 4–7 Applied.

MILITARY PLANE

MILITARY PLANE

FIG. 4–9. Spacing Letters.

4–7. Ink letters are made with a ball-pointed pen for somewhat heavy letters and with a Gillott 404, 303 or similar pen point for ordinary purposes. The pen may be dipped into the ink and the surplus shaken back into bottle or the quill may be used. The pen must be wiped as often as necessary to keep it clean and free from dried ink.

Letters with wide strokes can be easily made with one of the round point pens illustrated in Fig. 4–10. These are made in graded sizes to give different widths of lines.

4–8. Lettering devices are made with either openings or grooved plates to provide guides for lettering with specially designed pens. They are made for

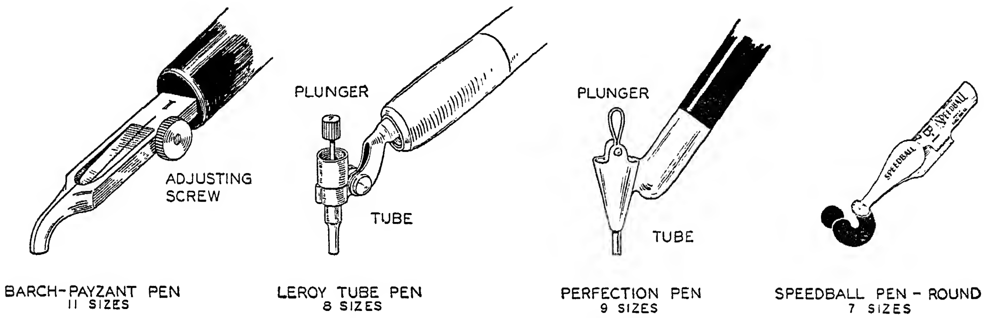


FIG. 4–10. Round-Point Pens.

various sizes of letters and require little skill beyond a knowledge of how to space the letters. One form of guide is the Wricoprint illustrated in Fig. 4–11, which can be obtained for capitals and lower-case letters, either vertical or inclined.

4–9. LETTERING EXERCISES. — Read Art. 2–16 before starting these exercises. Lettering practice must be done methodically and carefully to insure good results. These exercises, unless otherwise stated are for one-quarter of a four-part layout (Fig. 2–31). Guide lines must be ruled *very lightly* in pencil. Use a 2H pencil for guide lines and an H or F pencil for pencil lettering.

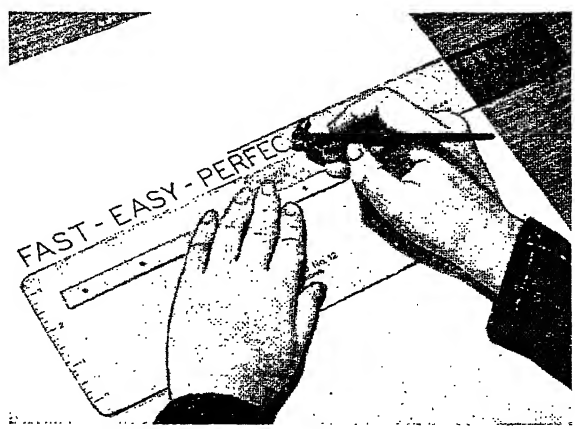


FIG. 4–11. Wricoprint.

In the following exercises either VERTICAL or INCLINED capital letters are to be made, as directed by the instructor. It is very desirable for the student to learn both forms. In this case use vertical capitals for all the exercises first and when proficient, work them with inclined capitals. Use a pencil unless otherwise directed.

Prob. 4–1. Fig. 4–12 or 4–13. — Vertical or inclined capital letters as directed by instructor. Draw horizontal guide lines 3/8 inch apart, drawing first line 1/2 inch below top of space. Make each of the following capital letters (3/8 inch high) three or more times: I, T, L, H, F, E, N, M, Z, Y, A, K, V, W, X, O, Q, C.

Prob. 4-2. Draw guide lines as for Prob. 4-1. Letter the following words. LEFT, HALF, LEVEL, LINE, METAL, TAIL WHEEL, MAIN, FIN, TAXI, NAVY, ELEVATE.

Prob. 4-3. Draw guide lines as for Prob. 4-1. Make each of the following capital letters three or more times: G, U, J, D, B, P, R, S, 8c, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0.

Prob. 4-4. Draw guide lines as for Prob. 4-1, and letter the following words: WING, FUSELAGE, AIRCRAFT, NACELLE, RUDDER, MONOCOQUE, COWLING, RIBS SPARS, AILERON, 10-986754-23.

Probs. 4-5, 4-6, 4-7, 4-8. Same as Probs. 4-1, 4-2, 4-3, 4-4 respectively but use Speedball or similar pen Style B, size 4 or smaller.

Prob. 4-9. Begin ⅜ inch below top of space, draw horizontal guide lines ¼ inch apart to provide for nine lines of ¼ inch letters with ¼ inch spaces between guide lines of letters. Make lines 6 inches long. Make each capital letter five times, three letters on each line.

Prob. 4-10. Same as Prob. 4-9 but use a ballpointed pen.

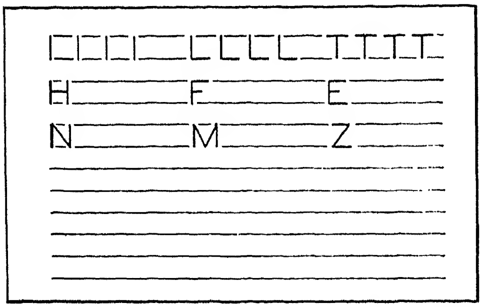


Fig. 4-12. Prob. 4-1.

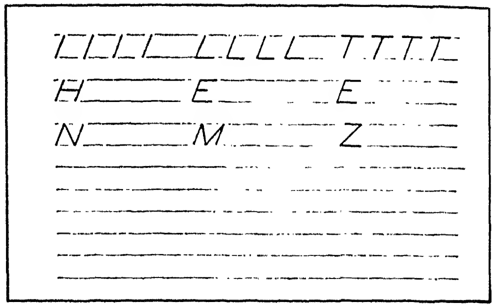


Fig. 4-13. Prob. 4-2.

Prob. 4-11. Draw guide lines as for Prob. 4-9. Letter the following words twice. TIME, LATE, EXAMINE, LAMINATE, ANODIZE, AMMUNITION MAGAZINE, HYDRAULIC FLAP OPERATING CYLINDER ASSEMBLY, BRAKE CONTROL ASSEMBLY, FLAP, LANDING GEAR.

Prob. 4-12. Same as Prob. 4-11 but use a ballpointed pen.

Prob. 4-13. Begin 1 inch below top of space and rule guide lines for thirteen lines of ⅛ inch high capitals separated by ⅛ inch spaces, or rule for thirteen lines with Braddock-Rowe triangle or Ames lettering instrument. Letter the following words: DRILL, REAM, 1941 MODEL 10, SPECIAL EQUIPMENT, WELD, SPRING, BRACKET, BORE, BUSHING, .250-28 NF-3 THREAD, .8750-D. SPLINE, 6 TEETH, PRESSURE TEST TO 250 LBS. PER SQ. IN., REINFORCEMENT, REMOVE SHARP CORNER AFTER WELDING, SEAL, RIVET, TORQUE PLATE, 19-14095 L.H. SHOWN, 19-14095-1 R.H. OPPOSITE. Begin 1½ inch from left side of space and end all lines about 1½ inch from right side of space.

Prob. 4-14. Same as Prob. 4-13 but use 303 or 404 Gillott pen.

4-10. Lettering-Guide Letters. — Many companies use lettering guides (see Fig. 4-11) of some form for part or all lettering. If guides are available the exercises should be practiced using the nearest available size of guide. Pencil letters are, of course, made freehand.

CHAPTER V

MULTIPLE VIEW DRAWINGS

5–1. Drawings are used to describe the shapes of the parts of an airplane in order to make it possible to manufacture the complicated machine that the present high-speed airplane has become. Without drawings the creation of the plane in metal would be impossible. Drawings are used to lay out and develop the whole airplane, to show how the parts are made, how they are assembled and how they are installed.

The shape of a part may be " pictured " on a plane surface (sheet of paper) in a number of ways (Fig. 5–1). A perspective may be drawn or, if the part has been made, a photograph may be taken. Mechanical pictorial methods may be used to make isometric or oblique drawings. These methods appear to

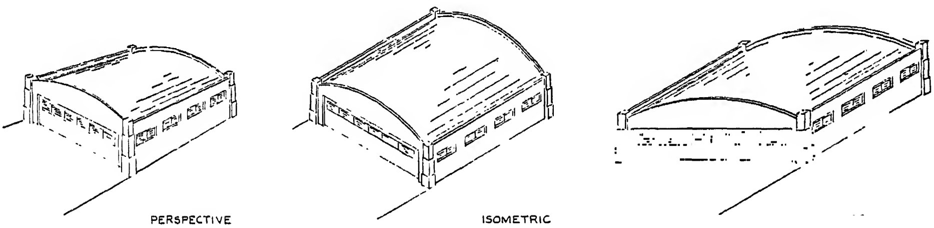


FIG. 5–1. Picture Drawings.

describe the part but upon examination it is evident that they do not give a complete and exact description of the shape of the part and that they do not show what is inside or *hidden* from view. Such picture drawings could not be used for the manufacture of airplanes. Orthographic projection as explained in this chapter forms the basis for the necessary working drawings and layouts.

5–2. The appearance of the object will vary with the position of the observer or direction of *the line of sight* (an imaginary line from the eye to a point on the object). If we imagine a series of lines of sight all parallel to each other and perpendicular to the picture plane (the plane upon which the object is represented) a view called an orthographic projection is obtained. Such a view will show the true shape and true size of any surface of the object which is parallel to the picture plane. It will show two dimensions. But an airplane and its parts occupy space in three directions. More than one view is, therefore, necessary to show the true shapes and true sizes of the various surfaces of a piece.

5–3. Since the true shape and true proportions of a construction or part can be accurately defined by orthographic projection, this method is generally used for engineering drawings. Reference to Figs. 5–2, 5–3, 5–4 and 5–5 will show how such views are used. Fig. 5–2 shows a picture and a three-view drawing of a block. Notice that the three orthographic views show the true shape of each face and that the true dimensions are shown for the WIDTH, HEIGHT and

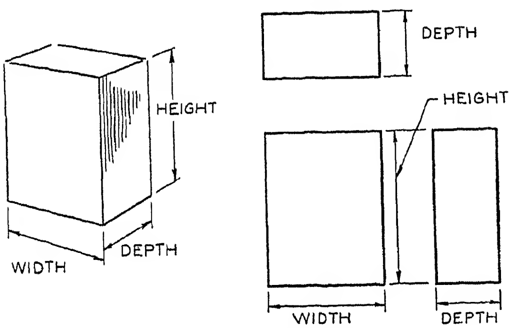


FIG. 5–2. Views of Block.

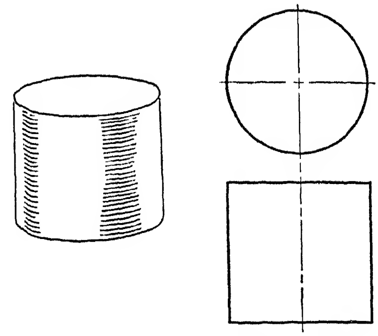


FIG. 5–3. Views of Cylinder.

DEPTH. Fig. 5–3 shows a picture and a two-view drawing of a cylinder. The top of the cylinder appears elliptical in the picture but the orthographic views show the circular form in the top view and the height in the front view. Notice that the diameter of the top view is the width of the front view, and that the two views are included between parallel vertical lines.

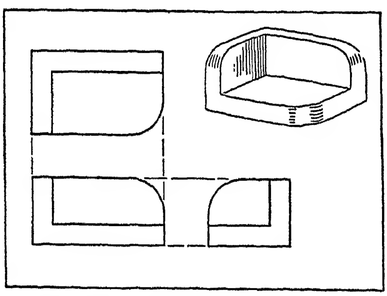


FIG. 5–4. Three-View Drawing.

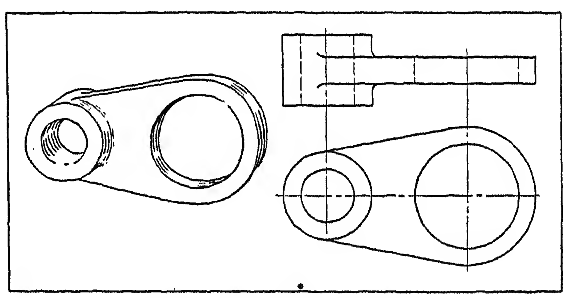


FIG. 5–5. Two-View Drawing.

The corner piece of Fig. 5–4 requires three views as shown. Note the arrangement of the views and the three dimensions; width, height and depth. The top and front views are included between parallel vertical lines and the front and side views are included between parallel horizontal lines. A picture and a drawing of a rod guide are shown in Fig. 5–5. Two views give all the necessary information.

Two or three views are generally sufficient for the drawing of a simple part. More views may be required to show the left side, bottom, or rear of the object

or to show surfaces at an angle. As many views are used as are necessary to give a complete description of the *true shape* of all the parts. Each view shows the object as viewed from a different direction.

5–4. Principal Views. — The front, top and side views are called the three principal views. The positions of these views are fixed by the position of the

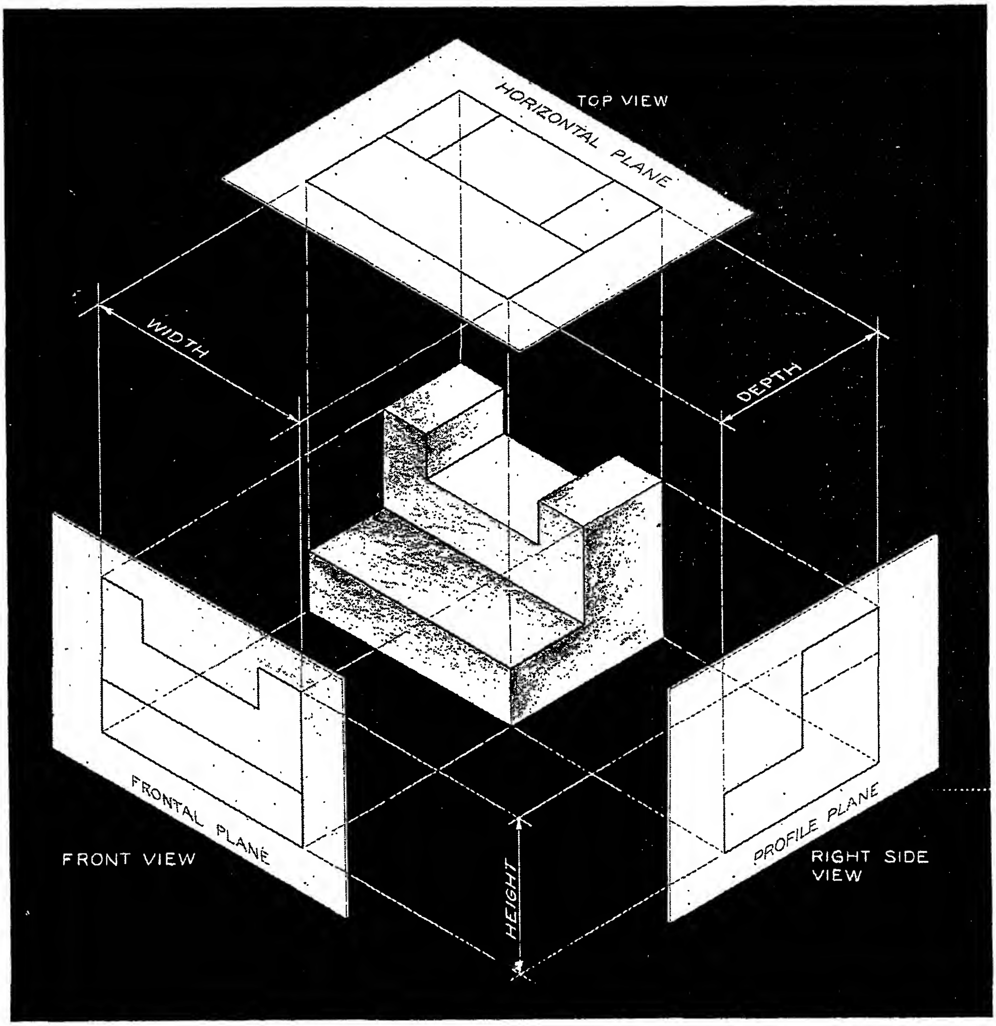


FIG. 5–6. The Principal Views.

object in space as shown in Fig. 5–6. It will be observed that the views represent the object as seen from directly in front, from above, and from the right side. The arrangement of the views when drawn on a sheet of paper is shown in Fig. 5–7. The top view is the same width as the front view and is placed directly above it. The side view is the same height as the front view and is

placed directly to the side of it. This arrangement of views is called third angle projection and is the American standard. First angle projection, used in some foreign countries, has the top view below the front view, and the right side view at the left of the front view.

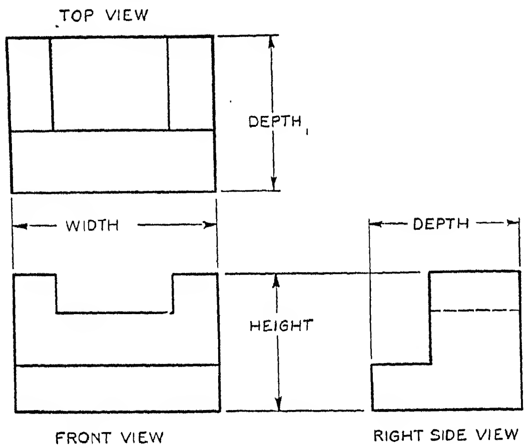


FIG. 5-7. Arrangement of Views.

5-5. Practical rules which will be of help in making and reading drawings are as follows:

1. Horizontal or WIDTH distances are the same in the top and front views. The top view is the same width as the front view.
2. Vertical or HEIGHT distances are the same in the front and side views.
3. Vertical or DEPTH distances in the top view are the same as horizontal or DEPTH distances in the side view.
4. The front of the top view is toward the front view.
5. The front of the side view is toward the front view.
6. Invisible or hidden surfaces or lines are represented by hidden (dotted) lines, made up of short dashes. See right side view of Fig. 5-7 where it is necessary to " look through " the object to locate the surface represented by the horizontal " hidden " line.
7. An inclined face will not show its true size in any of the principal views, Fig. 5-8.
8. A curved surface will not show in its true size in any views but it is described by them.
9. When more than the three principal views are used the American standard arrangement is shown in Fig. 5-9.
10. Sometimes it is desirable or necessary to place a side view in the *second position* or across from the top view as in Fig. 5-10.

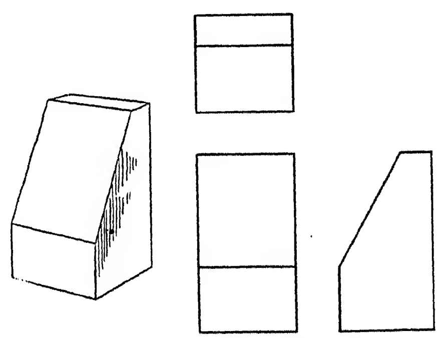


FIG. 5-8. An Inclined Surface.

5-6. Hidden lines are used to represent the interior or *hidden* parts of an object (Fig. 5-11). The views at *B* indicate better judgment than the views at *C* where more hidden lines are necessary. It is not possible to avoid all hidden lines. Hidden lines are somewhat harder to read than the visible lines and must be carefully drawn. A hidden line starts with a " dash " as at *A* in Fig. 5-12, when it represents a whole surface. When part of a line is full and part hidden a space is left between the full line and the hidden line as at *B* in Fig. 5-12.

Dashes should touch at corners as at C and D in Fig. 5–12. Hidden arcs should be drawn as shown in Fig. 5–12 at E.

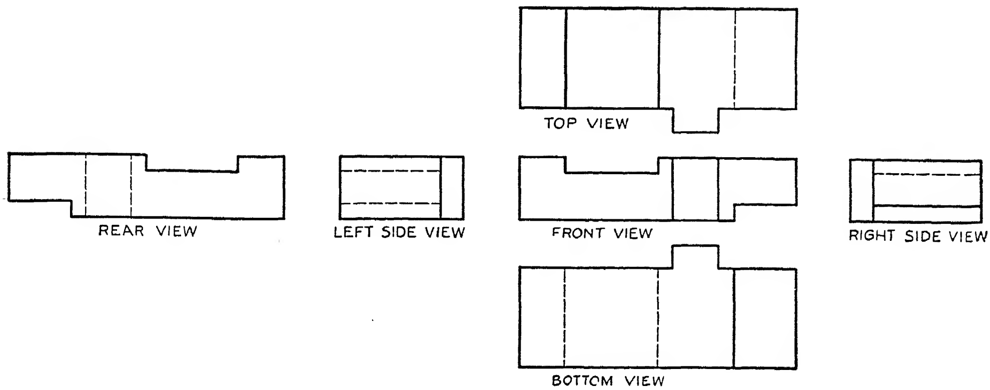


Fig. 5–9. Arrangement of Views. (*American Standard.*)

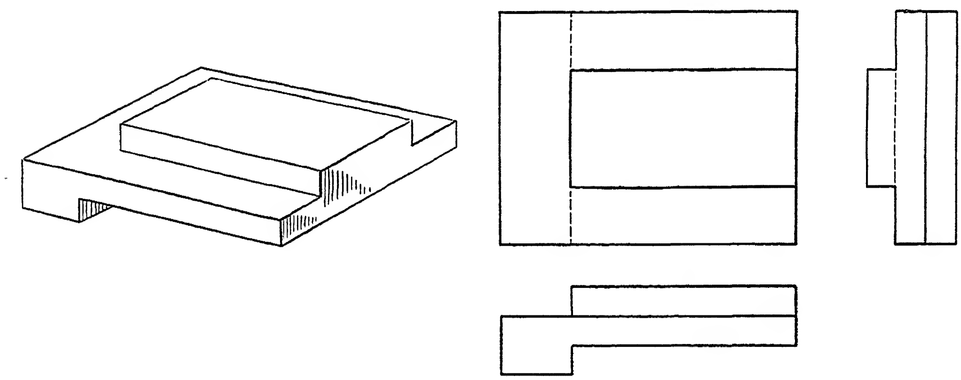


Fig. 5–10. Second Position of Side View.

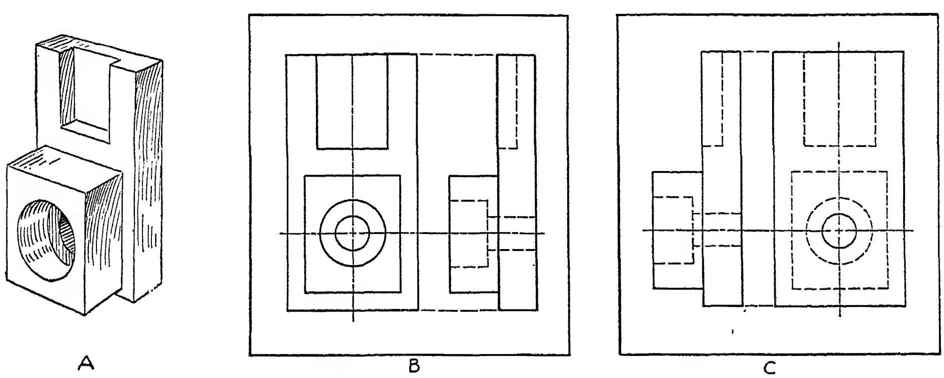


Fig. 5–11. Hidden Lines.

5–7. Inclined and rounded surfaces are represented as shown in Figs. 5–13, 5–14 and 5–15. The pictures and the views should be studied and compared so that the principles can be applied to the making and reading of drawings.

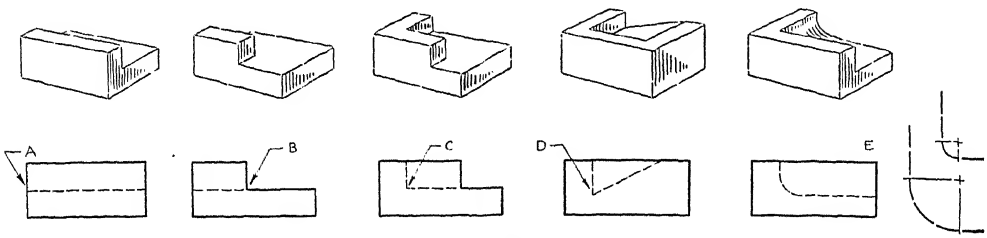


FIG. 5–12. Hidden Lines.

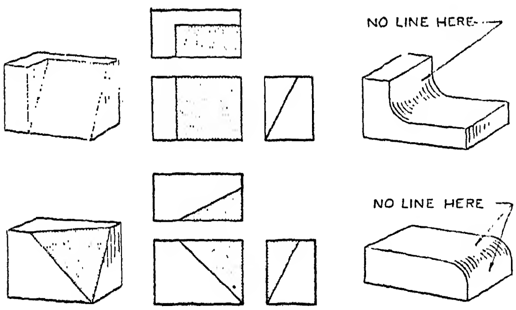


FIG. 5–13. Views for Study.

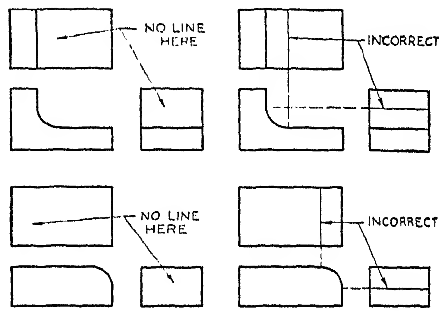


FIG. 5–14. Views for Study.

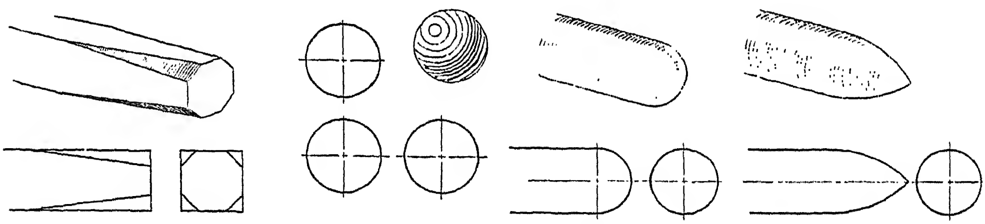


FIG. 5–15. Views for Study.

5–8. PROBLEMS. — Read Art. 2–16 before starting these problems. Most of these problems are planned for one-quarter of a four-part layout (Fig. 2–31). Dimensions are given on a number of problems for locating the views. Such dimensions are not to be put on the completed views. Do not dimension your drawing except when specified in the problem or by your instructor.

Probs. 5–1 to 5–4. Figs. 5–16 to 5–19. — Draw three complete views of the piece. Block in the three views very lightly, and work them up by projecting from one view to another. Check the depth in the top view with the same measurement in the side view.

Probs. 5–5 to 5–8. Figs. 5–20 to 5–23. — Draw three complete views of the piece. If necessary make a freehand sketch to plan the choice of views and position in the space.

Probs. 5–9 to 5–12. Figs. 5–24 to 5–27. — Draw three complete views of the piece.

Probs. 5–13 to 5–16. Figs. 5–28 to 5–31. — Draw three complete views. If necessary make a freehand sketch to plan the choice of views and position in the space.

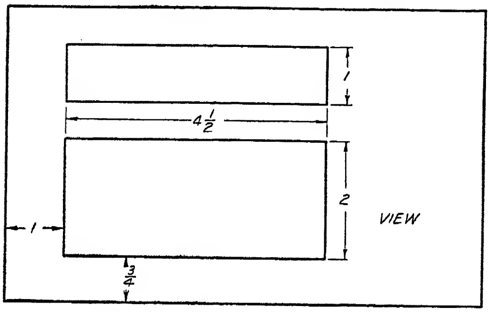


FIG. 5–16. Filler. Prob. 5–1.

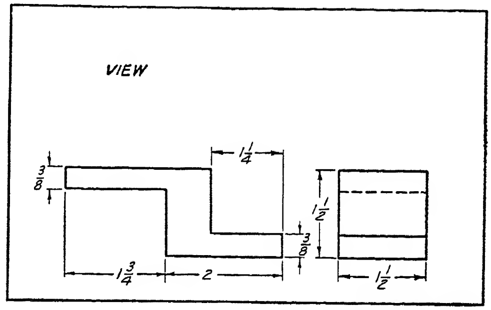


FIG. 5–17. Offset. Prob. 5–2.

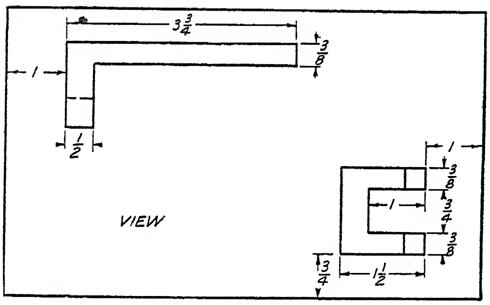


FIG. 5–18. Connector. Prob. 5–3.

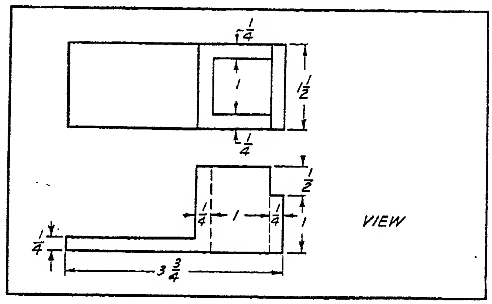


FIG. 5–19. Guide. Prob. 5–4.

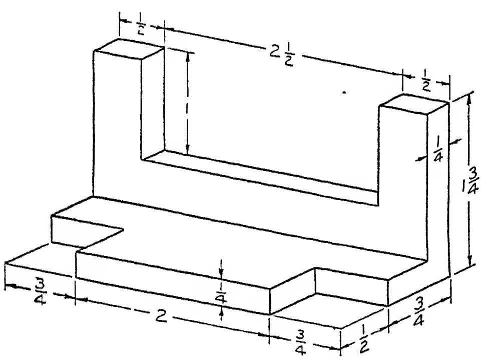


FIG. 5–20. Holder. Prob. 5–5.

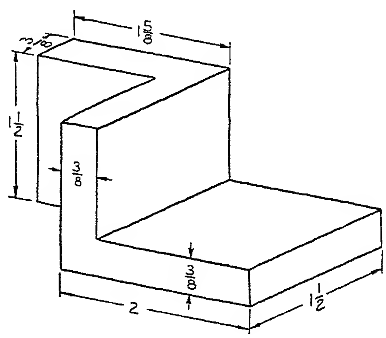


FIG. 5–21. Brace. Prob. 5–6.

Probs. 5–17–A to 5–17–O. Fig. 5–32. — The views shown in Fig. 5–32 are designed to aid in developing the power of visualization. A large number of solutions are possible for each problem. Measurements in only two directions are possible with one view as shown. Measurements in the third direction may be assumed. It is required to construct three views to form a complete description of some object.

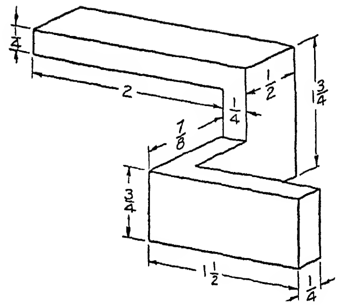


FIG. 5-22. Latch. Prob. 5-7.

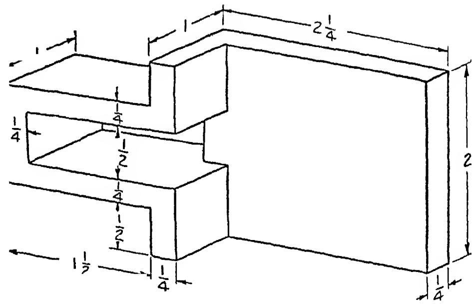


FIG. 5-23. Anchor. Prob. 5-8.

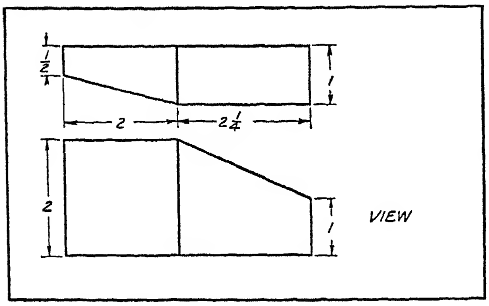


FIG. 5-24. Angle Set. Prob. 5-9.

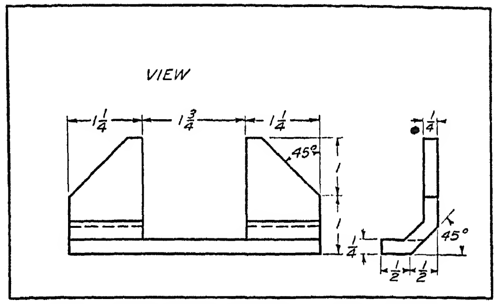


FIG. 5-25. Hinge Plate. Prob. 5-10.

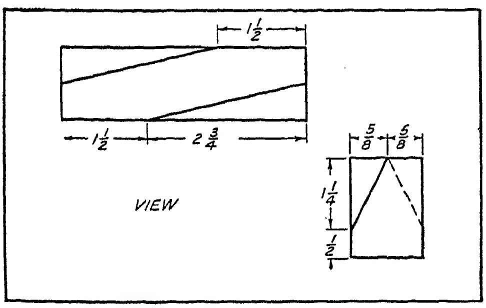


FIG. 5-26. Form Block. Prob. 5-11.

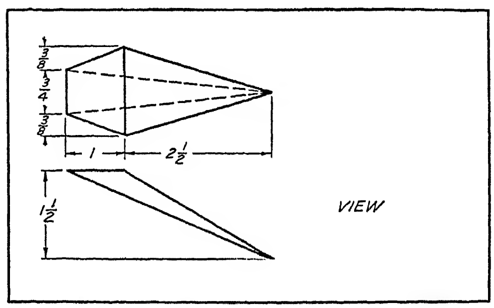


FIG. 5-27. Lug. Prob. 5-12.

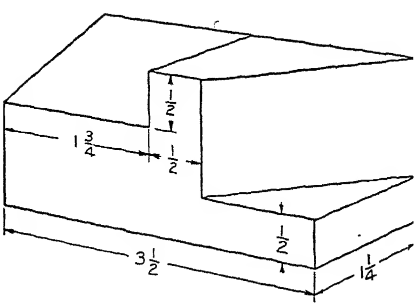


FIG. 5-28. Corner Former. Prob. 5-13.

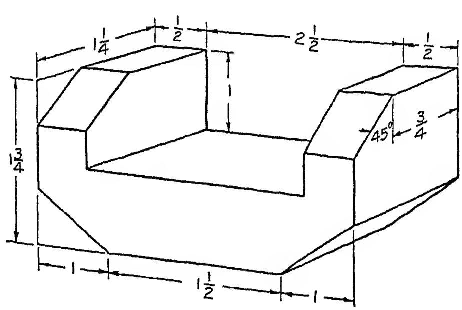


FIG. 5-29. Hinge Former. Prob. 5-14.

Use the view given as one view and supply two other views which will completely describe the object. The horizontal dimension of the view shown is twice the vertical dimension.

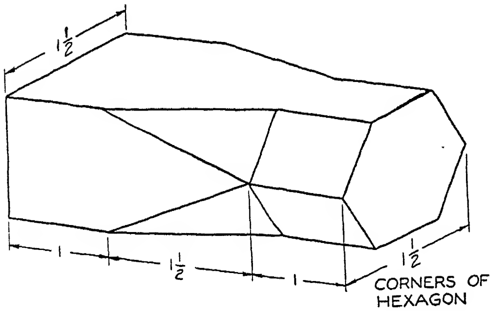


FIG. 5-30. Connector Former. Prob. 5-15.

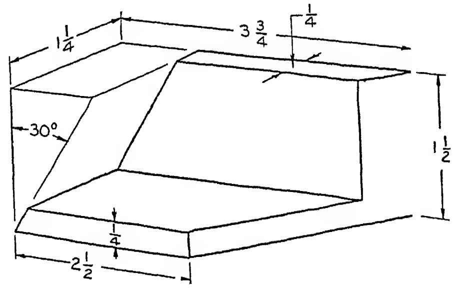


FIG. 5-31. Cut Angle. Prob. 5-16.

Dimensions may be assumed if the views are drawn with the instruments or the problems may be worked as freehand studies.

Probs. 5-18 to 5-27. Figs. 5-33 to 5-42. — Draw the necessary views of the parts assigned. Plan the arrangement and placing of the views in the space before starting to work up the views.

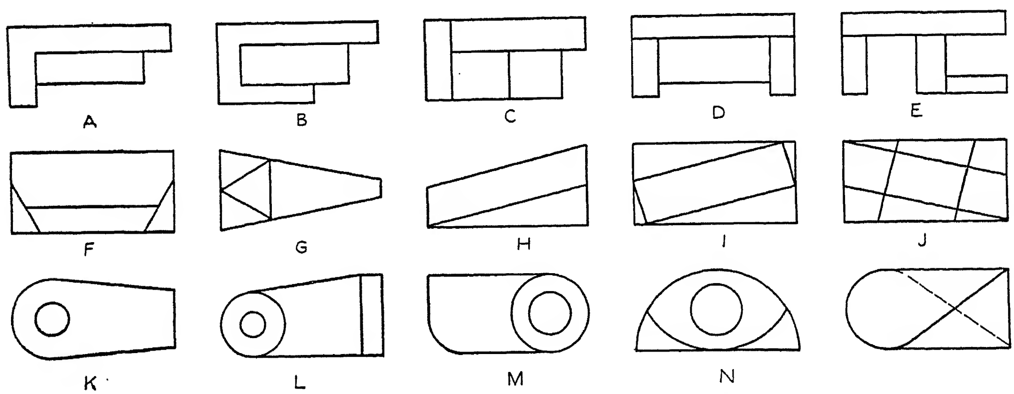


FIG. 5-32. Multiple View Studies. Prob. 5-17.

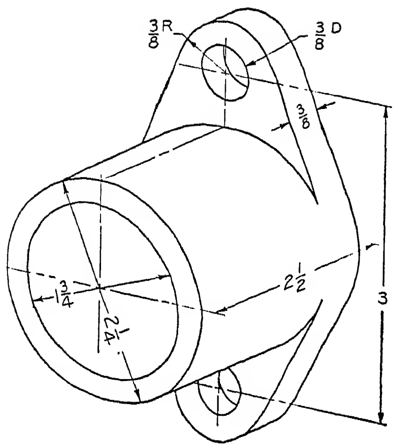


FIG. 5-33. Gland. Prob. 5-18.

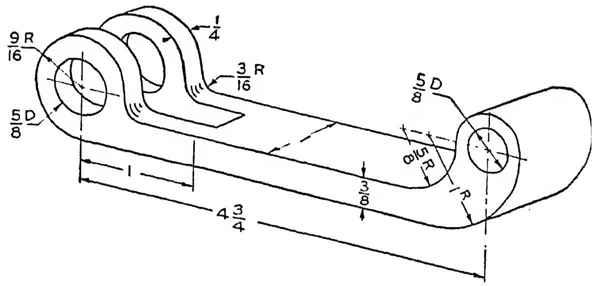


FIG. 5-34. Link. Prob. 5-19.

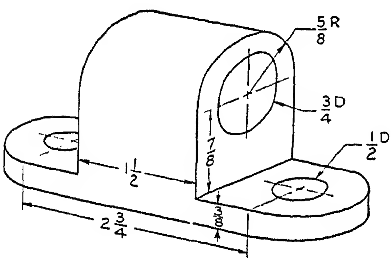


FIG. 5-35. Lug. Prob. 5-20.

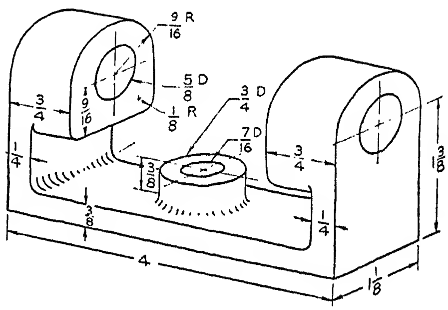


FIG. 5-36. Holder. Prob. 5-21.

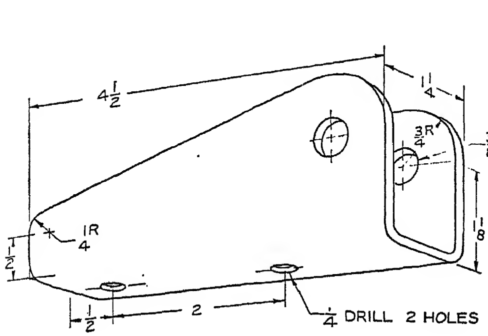


FIG. 5-37. Plate A. Prob. 5-22.

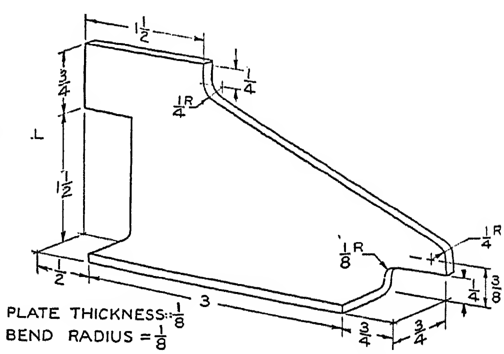


FIG. 5-38. Plate B. Prob. 5-23.

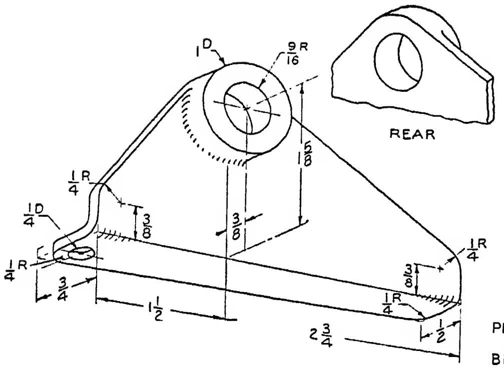


FIG. 5-39. Plate C. Prob. 5-24.

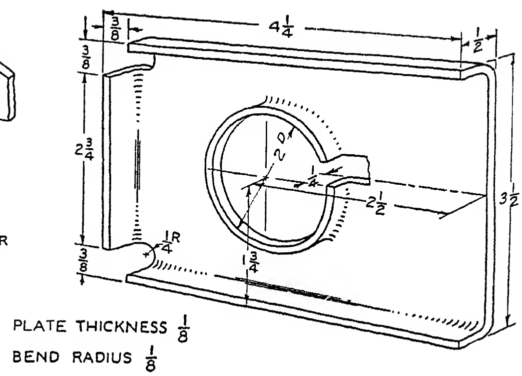


FIG. 5-40. Plate D. Prob. 5-25.

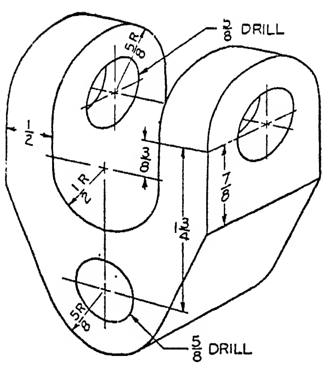


FIG. 5-41. Universal Joint. Prob. 5-26.

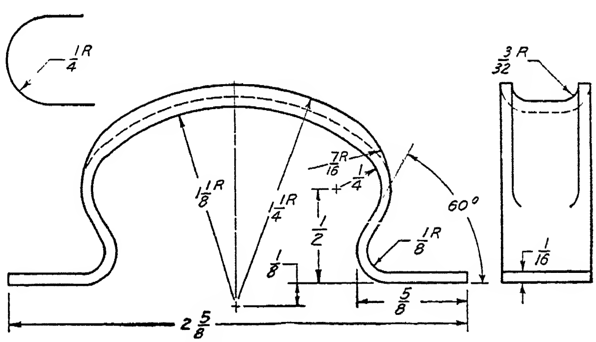


FIG. 5-42: Hatch Handle. Prob. 5-27.

CHAPTER VI

FREEHAND SKETCHING

6–1. The sketches of Leonardo da Vinci and his studies of the science of flight have caused him to be considered the first real pioneer of aviation. He made exhaustive studies on the flight of birds and made a number of sketches of flying machines (Fig. 6–1).

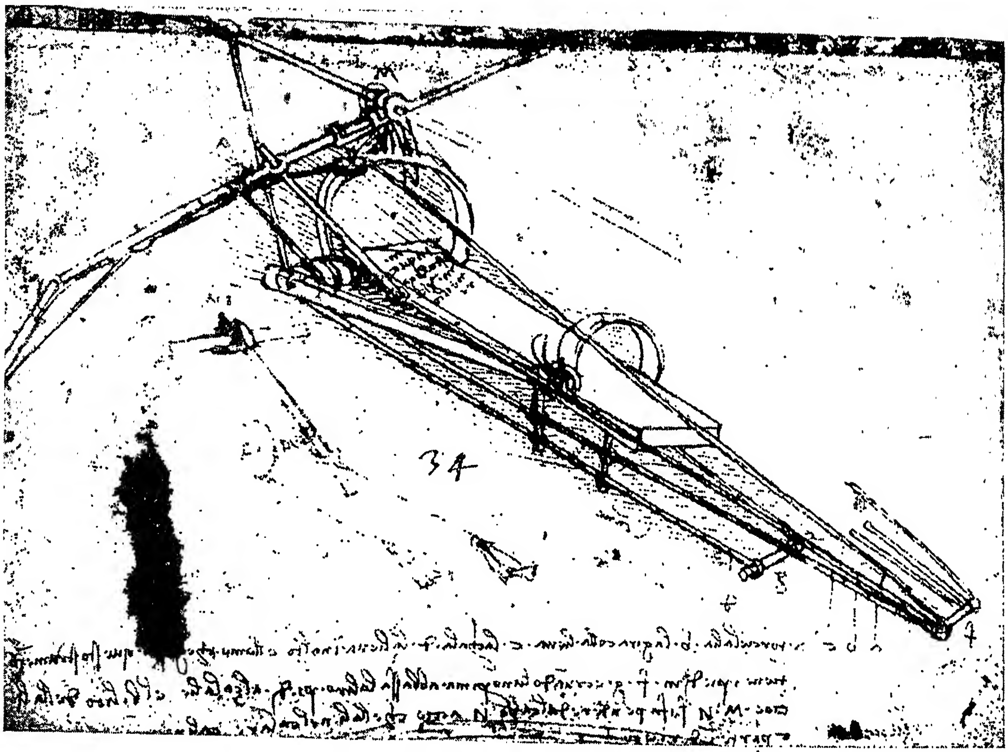


FIG. 6–1. Aviation Sketch by Leonardo da Vinci (1452–1519).
(*Photo by New York Public Library*)

Before and since the time of Leonardo da Vinci, sketches have ever been a helpful and practically indispensible means of developing and recording original ideas.

Sketching has no equal as an aid in the study of the science of shape description. It is a quick means of developing accuracy of thought, accuracy of observation and accuracy of proportion.

The ability to make sketches neatly, accurately and quickly is a necessary qualification of all who are engaged in aircraft engineering.

6–2. The materials for sketching consist of an F or H drawing pencil, pencil eraser, art gum, and paper. Either squared or plain paper may be used, but it is better to use plain paper at first so as not to be dependent upon the squares. The pencil should be kept well sharpened with a rather long point. The paper should be fastened to a small board or a " clip " board if a pad of paper is not used. EVERY sketch should have a title, the date, the name of the person who made it and any other pertinent information.

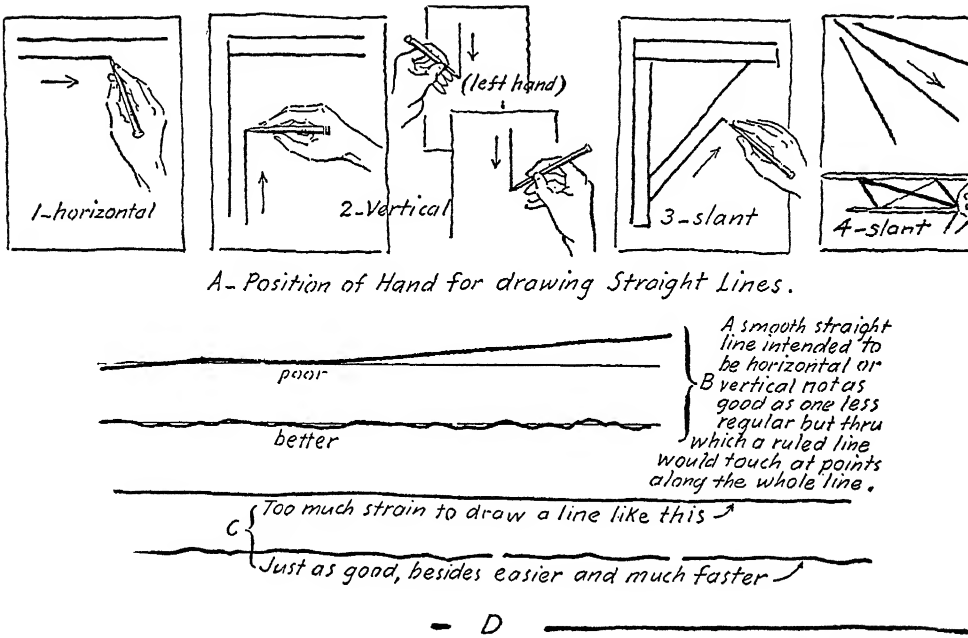


Fig. 6–2. Sketching Straight Lines.

6–3. Sketching Practice. — Straight lines, circles, arcs, and curves form the basis of all engineering sketching. Thorough practice of these fundamental lines will enable anyone to make a fair sketch.

Straight lines (Fig. 6–2)[1] may be sketched by making a succession of short lines or by marking a point at each end and sketching from one point to the other. Horizontal lines are sketched from left to right. Vertical lines may be sketched either up or down as may be more convenient. Inclined lines as at 3 in Fig. 6–2 are sketched either up or down. When lines are inclined as at 4 in Fig. 6–2 they may be sketched downward or the paper may be turned so that the line is horizontal.

[1] From *Freehand Drafting* by A. E. Zipprich. Pub. by D. Van Nostrand Co., Inc., New York.

Circles and arcs of circles may be sketched as illustrated in Fig. 6–3.[1] Draw center lines at right angles, space off radii on the center lines and in between them. If the radii are carefully estimated a satisfactory circle can be sketched through the points. Another method is to block in a square made up of four smaller squares (Fig. 6–4), and then sketch in one-fourth of the required circle

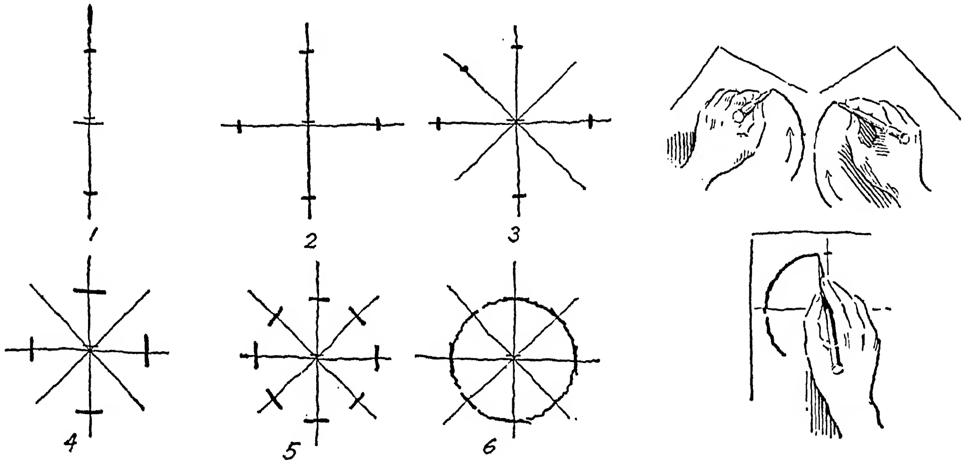


FIG. 6–3. Sketching Circles.

in each of the smaller squares. Curves are important for aircraft sketching. First locate a number of points on the curve, (and tangent straight lines, if any), then sketch lightly through the points and tangent to the straight lines (Fig. 6–5).

6–4. Making a Sketch. — To make a sketch the following order may be pursued. First examine the object (Fig. 6–6 at 1), determine the number of views necessary to give a complete description of it, and observe the proportions.

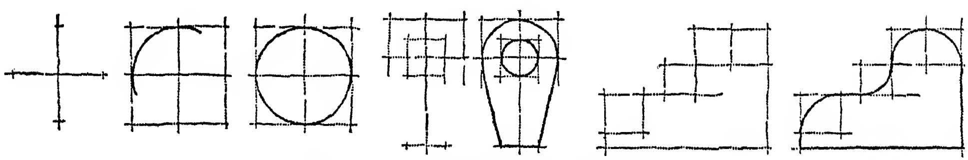


FIG. 6–4. Blocking-In Construction.

tions. Then proceed to locate the center lines and "block-in" each of the views with straight lines regardless of curves (Fig. 6–6 at 2). Block-in the details, sketch the various features, curves and arcs (Fig. 6–6 at 3), and finally brighten up the lines wherever necessary to make all parts clear and definite (Fig. 6–6 at 4).

When a complete working sketch is made, the dimensions and notes must be added as described in later chapters for regular drawings made with instruments.

[1] See footnote on page 55.

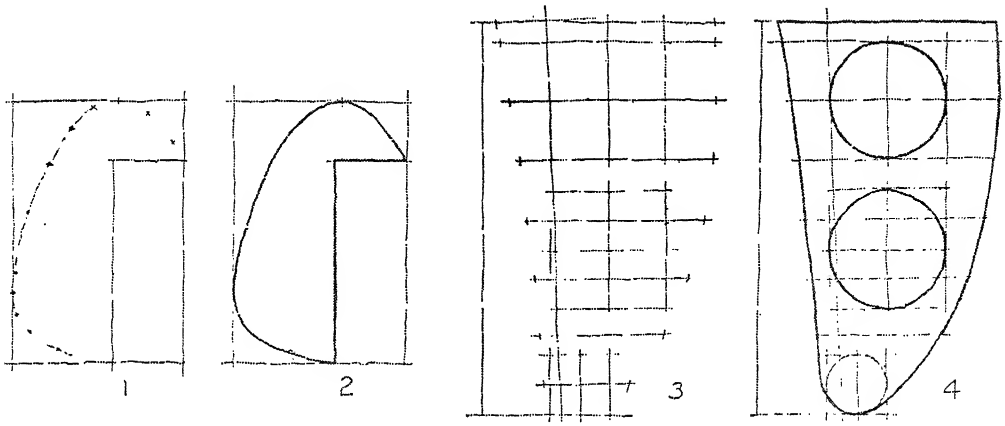


FIG. 6-5. Curve Sketching.

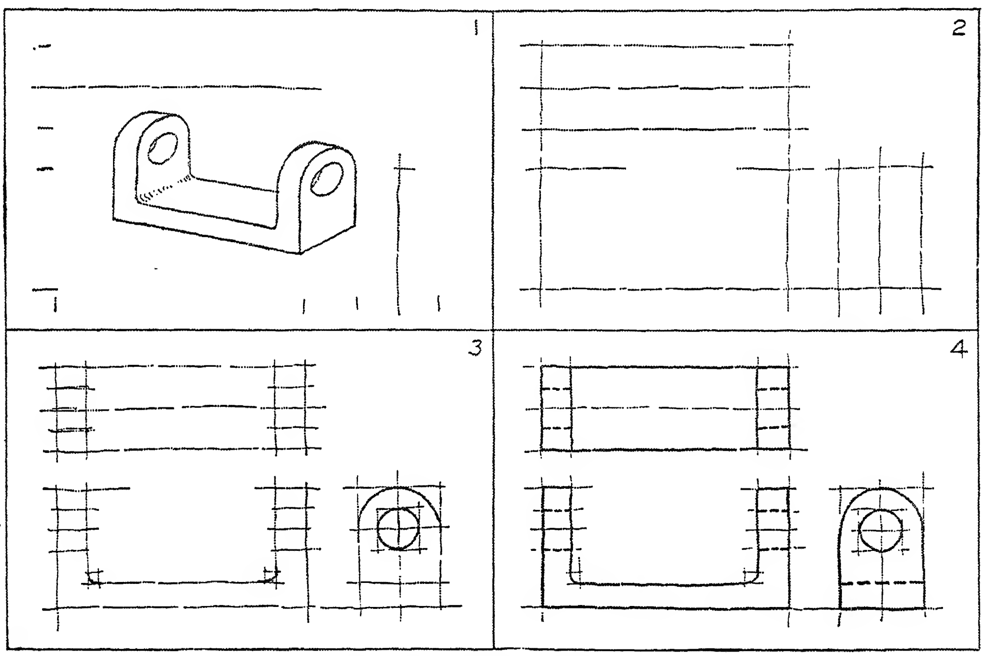


FIG. 6-6. Making a Sketch.

6-5. PROBLEMS. — Proficiency in sketching comes from careful practice. The following problems are intended to provide the means for development of facility in the use of the pencil, accuracy of observation, a sense of proportion, and further study of multiple view drawing. These problems will serve as a foundation for independent sketching of airplane parts and airplanes.

The size of paper suggested is 8½″ × 11″ but other sizes may be used if desired.

Group 1. Technique

Probs. 6-1 to 6-9. Figs. 6-7 to 6-15. — Sketch exercises shown. Two exercises may be sketched on an 8½″ × 11″ sheet, or four on a regular 11″ × 17″ sheet. Rectangles may be estimated in the ratio of 6 inches wide and 4 inches high.

Probs. 6-10 to 6-21. Figs. 2-22 to 2-33. — Sketch freehand. Assume distances proportional to the figures.

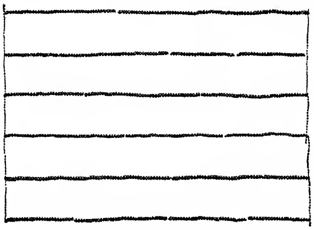


Fig. 6-7. Prob. 6-1.

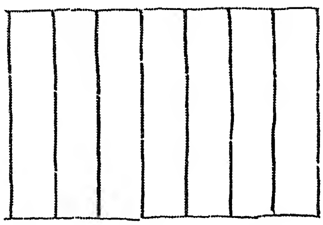


Fig. 6-8. Prob. 6-2.

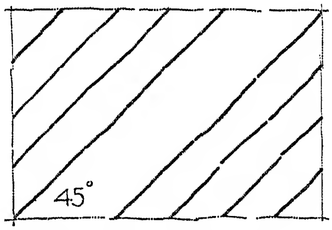


Fig. 6-9. Prob. 6-3.

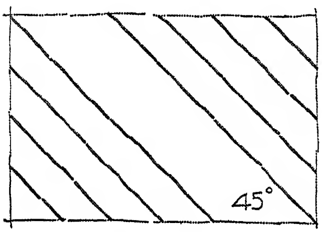


Fig. 6-10. Prob. 6-4.

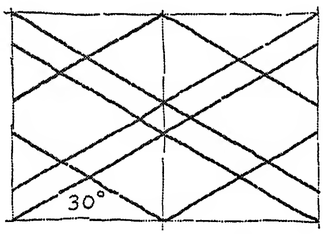


Fig. 6-11. Prob. 6-5.

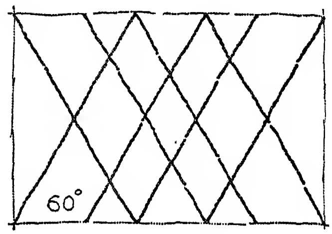


Fig. 6-12. Prob. 6-6.

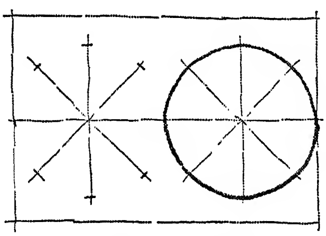


Fig. 6-13. Prob. 6-7.

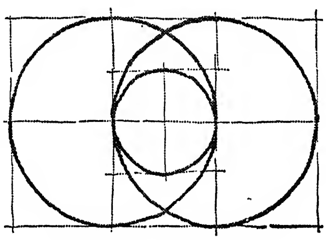


Fig. 6-14. Prob. 6-8.

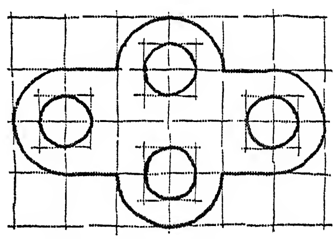


Fig. 6-15. Prob. 6-9.

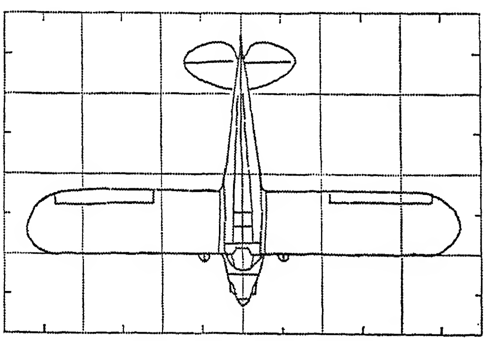


Fig. 6-16. Prob. 6-22.

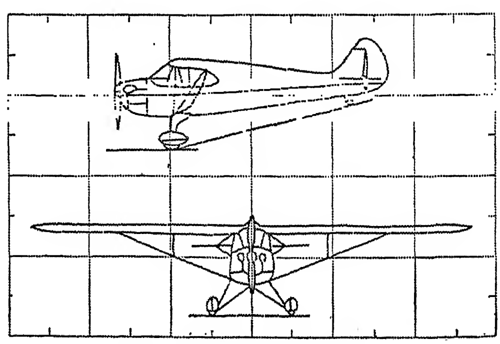


Fig. 6-17. Prob. 6-23.

Probs. 6–22 and 6–23. Figs. 6–16 and 6–17. — Sketch rectangles in the proportion shown, and divide into squares with very light lines. Sketch the airplane views.

Prob. 6–24. Fig. 3–65. — Make a freehand sketch of the runways for the airport.

Prob. 6–25. Fig. 3–1. — Make a freehand sketch of the runways for the airport.

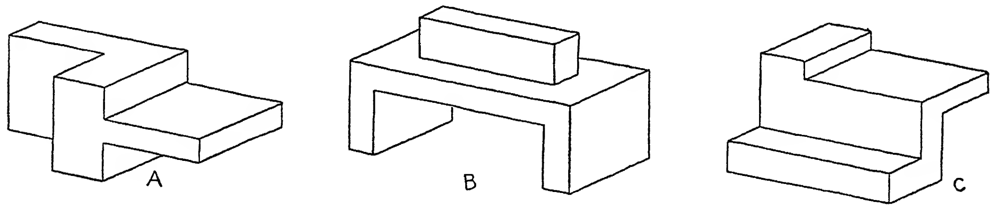


FIG. 6–18. Probs. 6–26, 6–27, 6–28. Probs. 11–35, 11–36, 11–37.

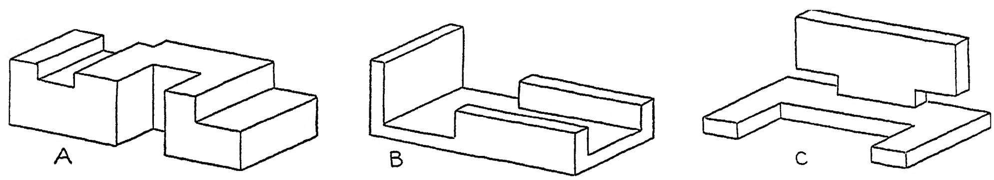


FIG. 6–19. Probs. 6–29, 6–30, 6–31. Probs. 11–38, 11–39, 11–40.

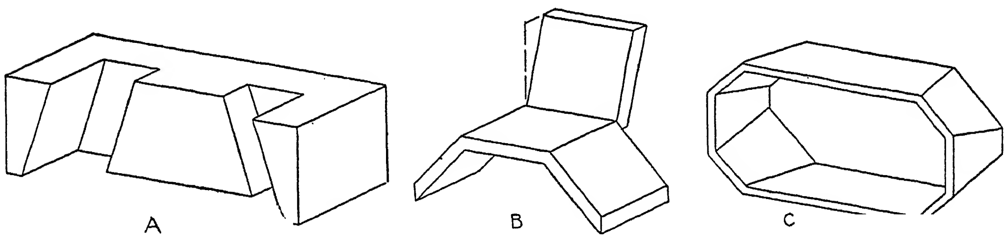


FIG. 6–20. Probs. 6–32, 6–33, 6–34. Probs. 11–41, 11–42, 11–43.

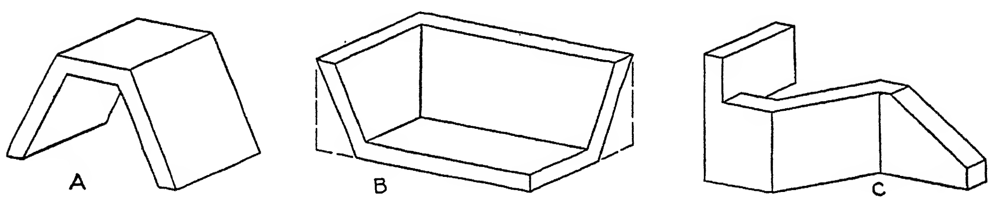


FIG. 6–21. Probs. 6–35, 6–36, 6–37. Probs. 11–44, 11–45, 11–46.

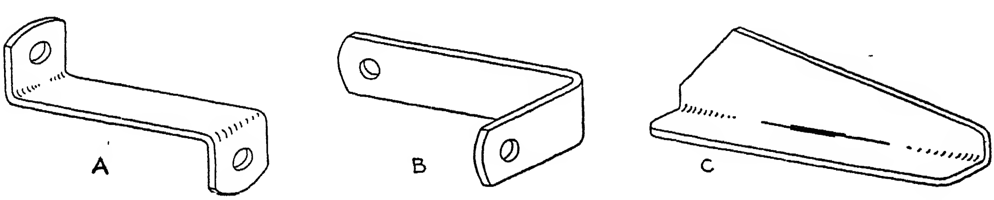


FIG. 6–22. Probs. 6–38, 6–39, 6–40. Probs. 11–47, 11–48, 11–49.

Group 2. Multiple-View (Orthographic) Sketches

Probs. 6–26 to 6–54. Figs. 6–18 to 6–27. — Make neat two- or three-view sketches of the parts shown. Choose the views with care and observe the proportions of the parts.

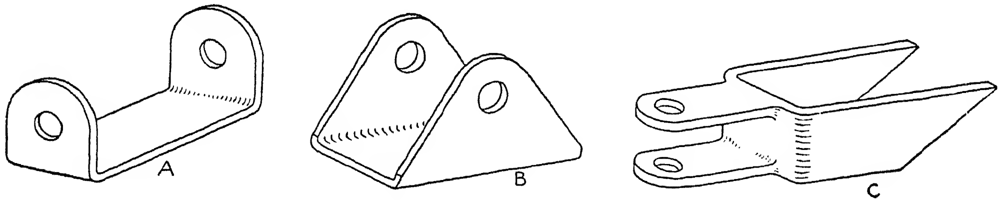


Fig. 6–23. Probs. 6–41, 6–42, 6–43. Probs. 11–50, 11–51, 11–52.

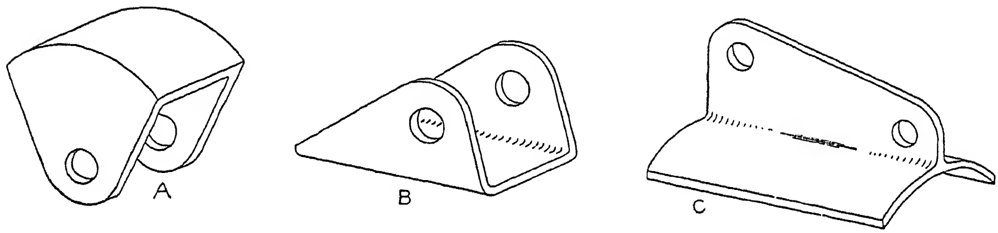


Fig. 6–24. Probs. 6–44, 6–45, 6–46. Probs. 11–53, 11–54, 11–55.

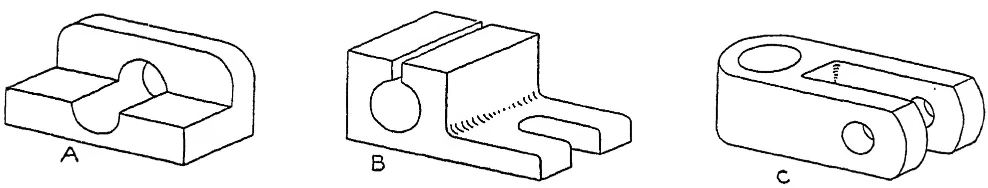


Fig. 6–25. Probs. 6–47, 6–48, 6–49. Probs. 11–56, 11–57, 11–58.

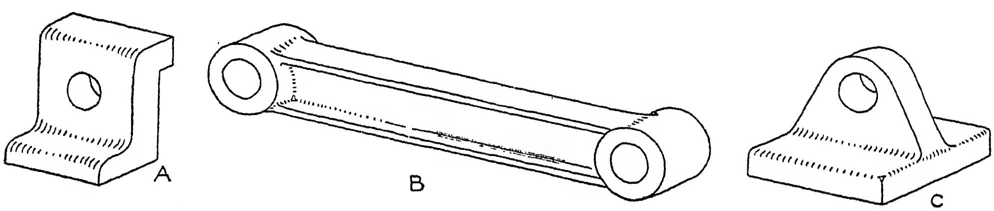


Fig. 6–26. Probs. 6–50, 6–51, 6–52. Probs. 11–59, 11–60, 11–61.

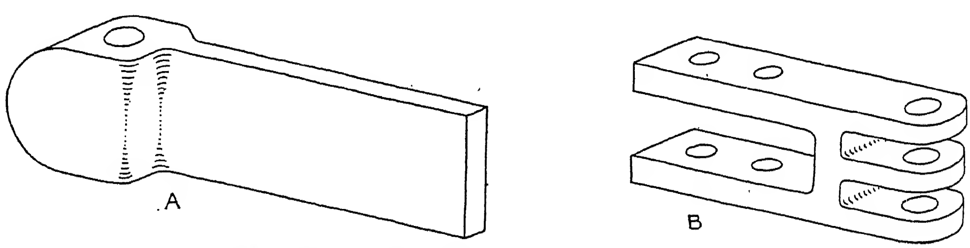


Fig. 6–27. Probs. 6–53, 6–54. Probs. 11–62, 11–63.

CHAPTER VII

AUXILIARY VIEWS

7–1. The principal views of a part show the true shapes of the surfaces which are parallel to the frontal, horizontal and profile (side) planes. Conditions sometime occur when it is necessary to show true shapes and arrangements which are not parallel to the principal planes. In such cases auxiliary views are used as in Fig. 7–1.

7–2. An auxiliary view is obtained by looking directly at the inclined surface (perpendicular lines of sight). There are three kinds of auxiliary views as indicated in Figs. 7–2, 7–3 and 7–4.

(1) **Auxiliary Elevation.** An auxiliary view which shows height. Fig. 7–2 shows an auxiliary elevation.

(2) **Right- or Left-Auxiliary View.** An auxiliary view which shows depth. Fig. 7–3 shows a right-auxiliary view.

(3) **Front- or Rear-Auxiliary View.** An auxiliary view which shows width. Fig. 7–4 shows a front-auxiliary view.

The partial views of a gear case in Fig. 7–5 include a left-auxiliary view, and the *Lockheed* sample drawing of Fig. 7–6 illustrates front- and rear-auxiliary views projected from the side view.

7–3. Auxiliary View — Center-Line Method. — If the inclined face is the same on both sides of a center line, the auxiliary view may be drawn by working from a center line (Fig. 7–7). Draw a center line for the auxiliary view parallel to the inclined face. A line through the front view of point 1, perpendicular to the inclined face will cross the inclined center line and locate point 1 on the right-auxiliary view. Locate points 2 and 3 in the auxiliary view by measuring on each side of the center line. These are DEPTH distances and can be taken from the top view. Depth distances are vertical distances in the top view and are measured perpendicular to the center line of the auxiliary view. All points in the auxiliary view are located by sight lines drawn from the front view (perpendicular to the auxiliary plane). The auxiliary view may be of the complete object or only the inclined surface.

7–4. Auxiliary View — Reference-Line Method. — The center line is a reference line for a symmetrical or near symmetrical part. To draw an auxiliary view of a non-symmetrical part it is generally desirable to use reference lines as in Fig. 7–8. Draw reference lines for the front view and for the auxiliary view. The reference line for the auxiliary view is drawn parallel to the inclined surface. A line through the front view of point 1, perpendicular to the inclined surface will cross the auxiliary reference line and locate point 1 on the auxiliary view. All

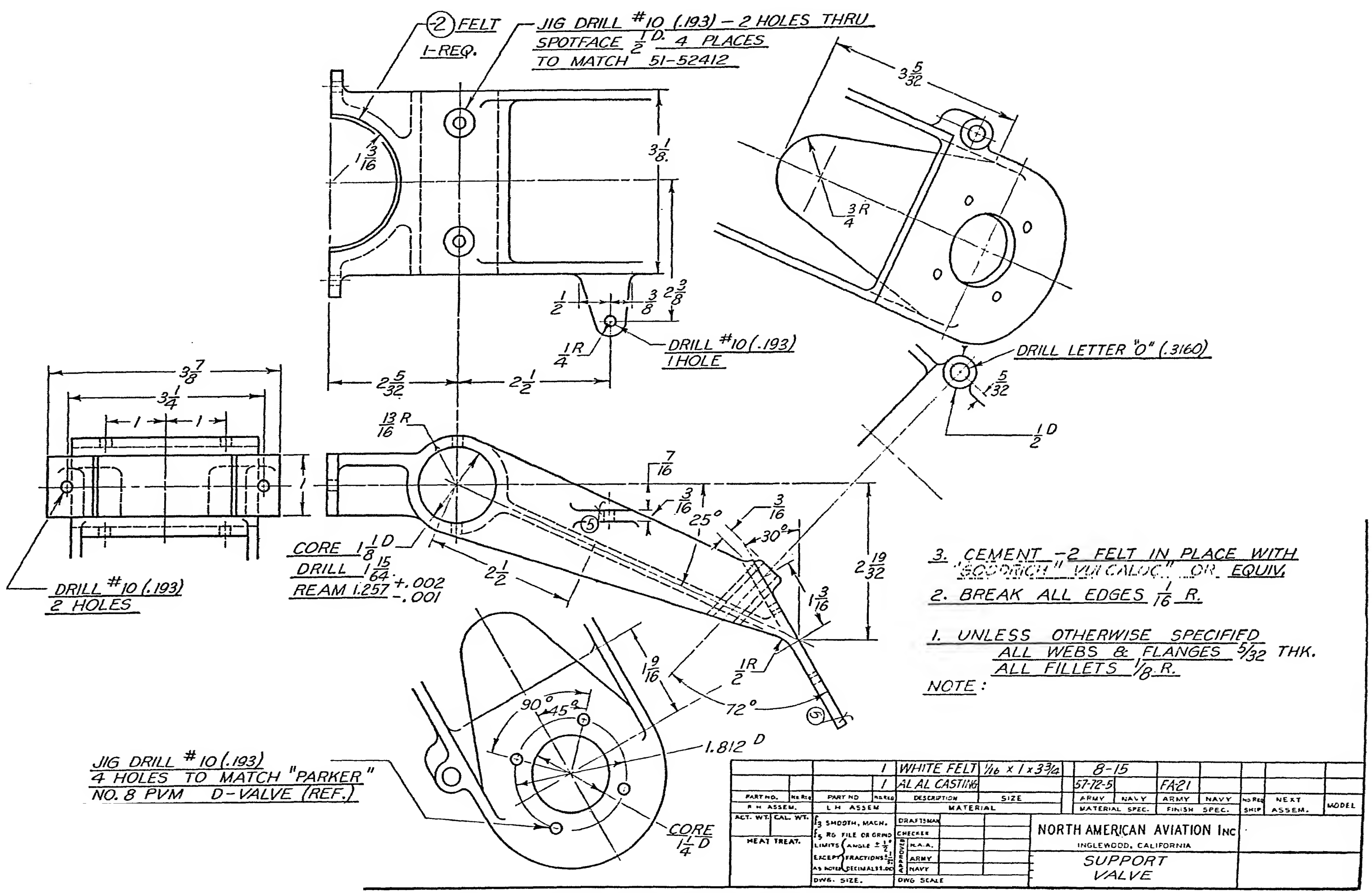


FIG. 7-1. A Drawing with Auxiliary Views. Prob. 14-5.

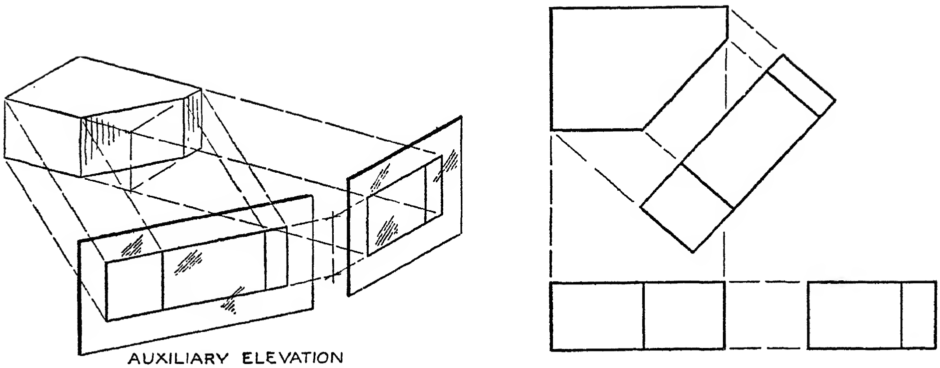


FIG. 7–2. Auxiliary Elevation.

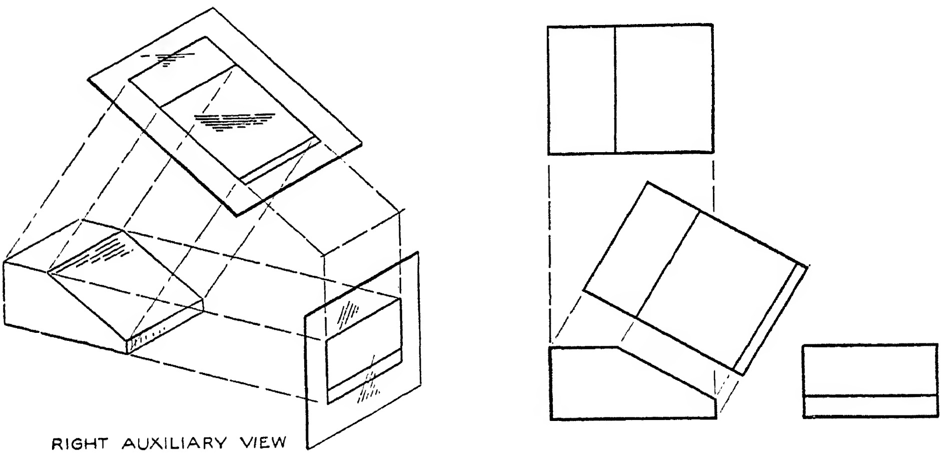


FIG. 7–3. Right-Auxiliary View.

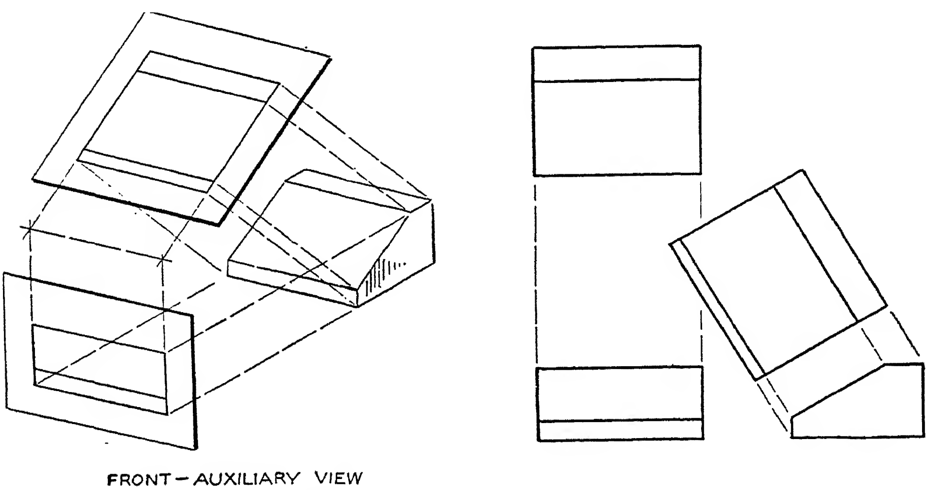


FIG. 7–4. Front-Auxiliary View.

other points are located by projecting from the front view and measuring from the reference line as for point 2. Remember that horizontal distances in the side view are depth distances and are measured perpendicular to the reference line in the auxiliary view — in this case toward the front.

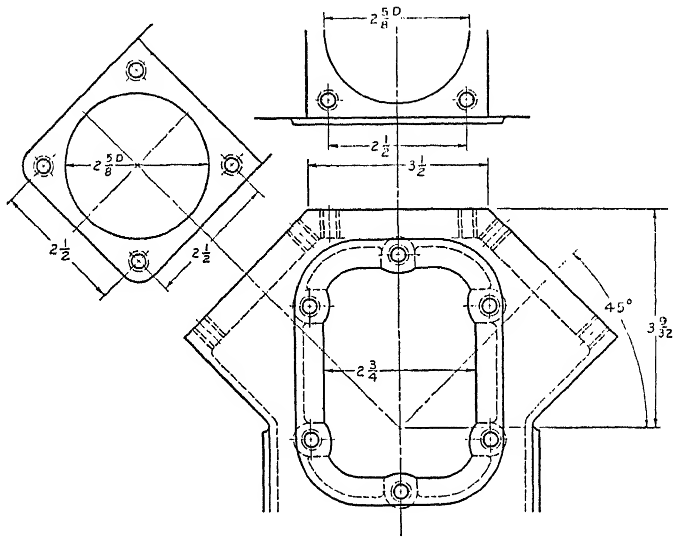


Fig. 7–5. Left-Auxiliary View.

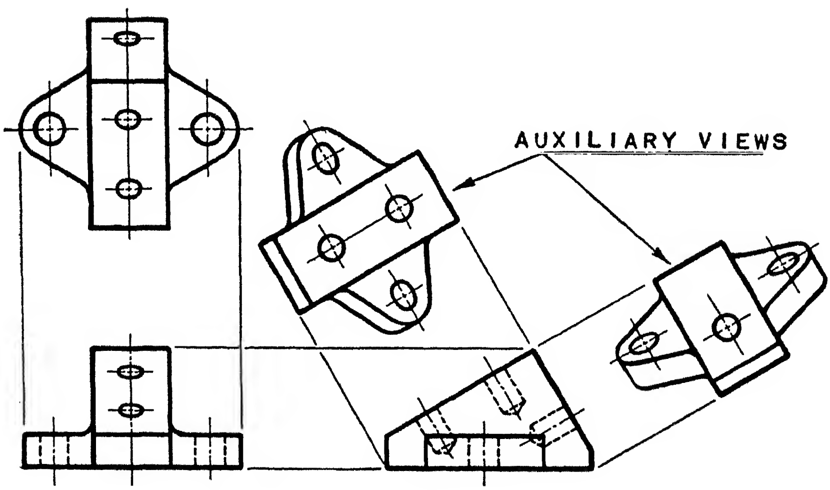


Fig. 7–6. Front- and Rear-Auxiliary Views.

7–5. Auxiliary View with Curves. — Curves are drawn on auxiliary views by taking a number of points and locating them in the auxiliary view by one of the methods just described. In Fig. 7–9, select a number of points such as 1 and 2 on the side view and locate them on the front view. Project from the side view

perpendicular to the cut surface. Points are measured on each side of the center lines in the front and auxiliary views. When sufficient points have been located draw a smooth curve through them. The inclined surface only is shown.

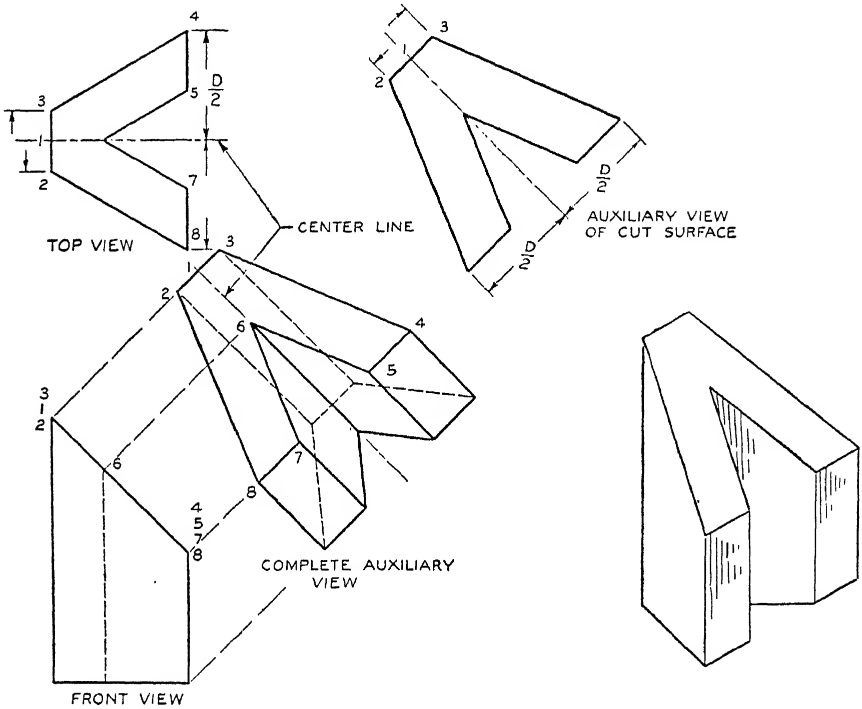


FIG. 7–7. Center-Line Method.

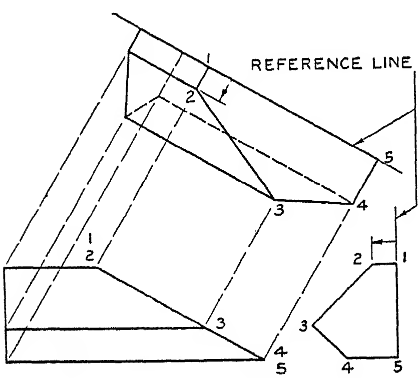


FIG. 7–8. Reference-Line Method.

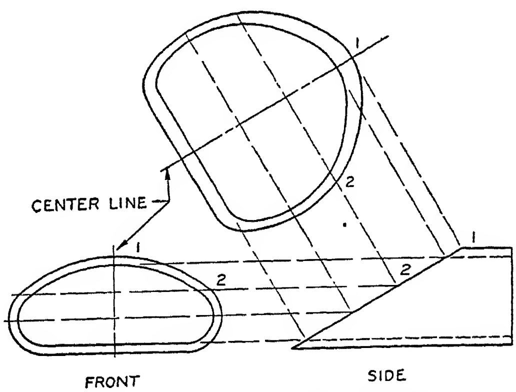


FIG. 7–9. Auxiliary View with Curves.

7–6. PROBLEMS. — Read Art. 2–16 before starting these problems. Most of these problems are planned for one-quarter of a four-part layout (Fig. 2–31).

Probs. 7-1-A to 7-1-M. Fig. 7-10. — Draw the top, front, and complete auxiliary views of the parts, given the top views, *A* to *M*. Horizontal distance in top view is 1¼ inches, vertical dimension is 1 inch, for all problems. Angle of inclined top face is 45° with the horizontal. Height is 1½ inches for all these problems.

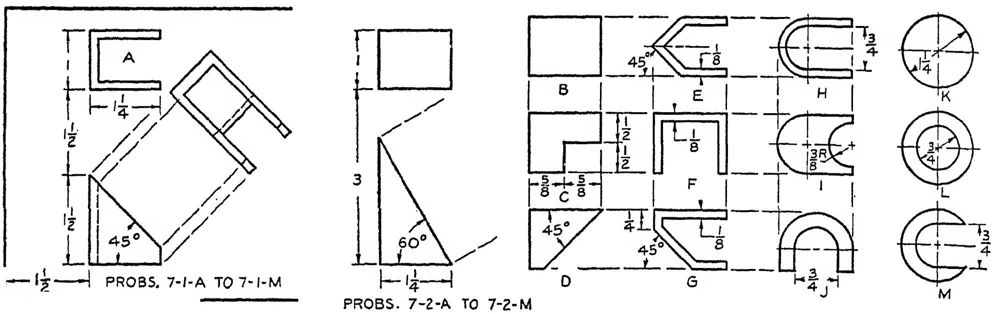


FIG. 7-10. Probs. 7-1-A to 7-1-M and 7-2-A to 7-2-M.

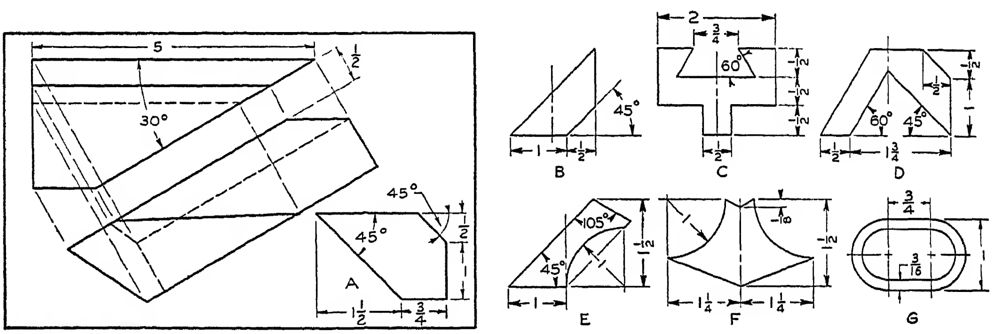


FIG. 7-11. Probs. 7-3-A to 7-3-G.

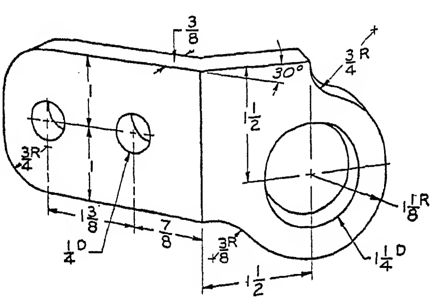


FIG. 7-12. Angle Tie. Prob. 7-4.

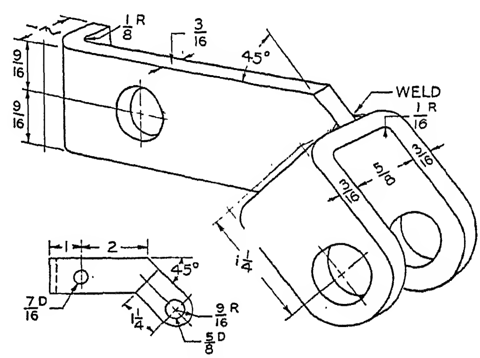


FIG. 7-13. Hinge. Prob. 7-5.

Probs. 7-2-A to 7-2-M. Fig. 7-10. — Draw the top, front and complete auxiliary views of the parts, given the top views, *A* to *M*. Horizontal distance in top view is 1¼ inches, vertical dimension is 1 inch for all problems. Angle of inclined top face is 60° with the horizontal. Height is determined by inclined face as indicated.

Probs. 7-3-A to 7-3-G. Fig. 7-11. — Draw the end and top views and the complete auxiliary views of the parts, given the end views *A* to *G*. The angle and horizontal dimension shown for *A* is the same for all of these problems.

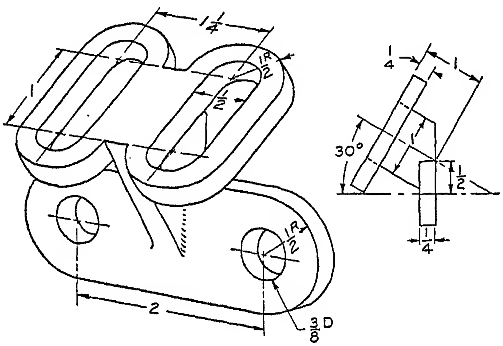


Fig. 7-14. Double Base. Prob. 7-6.

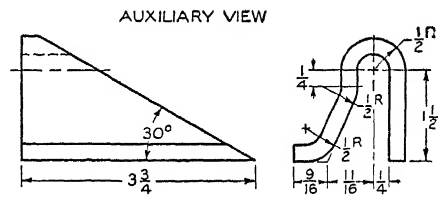


Fig. 7-15. Special Shape. Prob. 7-7.

Probs. 7-4 to 7-6. Figs. 7-12 to 7-14. — Draw the view which shows the angle, and the necessary auxiliary and part views, to represent the piece shown.

Prob. 7-7. Fig. 7-15. — Draw two views shown and a complete auxiliary view.

CHAPTER VIII

SECTIONAL VIEWS

8–1. Sectional Views. — When it is hard to show interior details or certain shapes with regular views or hidden lines, sectional views, obtained by imaginary cutting planes, may be used. Such sectional views are made by considering the object or construction to be cut by a plane and the part in front of the plane taken away.

A sectional view of an aircraft engine is illustrated in Fig. 8–1. Notice the large number of parts shown and consider how many of them would be hidden from view in an exterior view. If one attempted to indicate the interior parts and construction by hidden lines the result would be so confusing as to be very difficult, if not impossible, to understand.

8–2. To Draw a Sectional View. — The regular exterior views of a bearing housing are shown in Fig. 8–2 and a picture with an imaginary cutting plane in Fig. 8–3. The part in front of the cutting plane has been removed in Fig. 8–4 where the exposed cut surface is indicated by uniformly spaced parallel lines, generally inclined. Such a surface is said to be *section-lined* or *cross hatched.* A sectional view drawing is shown in Fig. 8–5. Note that the left-hand view is complete and that the edge of the cutting plane is indicated by the line *A–A*.

8–3. The general practice is to leave out the hidden lines on sectional views except where they are necessary for dimensioning or to make the shape clear. Details beyond the cutting plane may be left out unless they are necessary to describe the object.

When the location of a section is evident the heavy cutting plane line with letters and arrows need not be used.

8–4. Placing Sectional Views. — In general a sectional view should be placed in the same position relative to another view as the corresponding full view — that is on the correct side of the plane with respect to the arrows (Fig. 8–6). The position shown at Fig. 8–7, where the section is placed on an extension of the cutting plane line, is sometimes desirable. Under some circumstances the section may be placed as in Fig. 8–8 where the correct view is placed on the wrong side of the arrows. When space does not permit placing the section in a desired position or when a series of related sections are used, rotated or removed sections may be placed as in Fig. 8–9. Such sections must, of course, be correctly drawn with respect to the point of view as indicated by the cutting plane arrows. The indication of the angle of rotation and the note ROTATED X° directs attention to the fact that the section is not in the proper position on the drawing. Such a

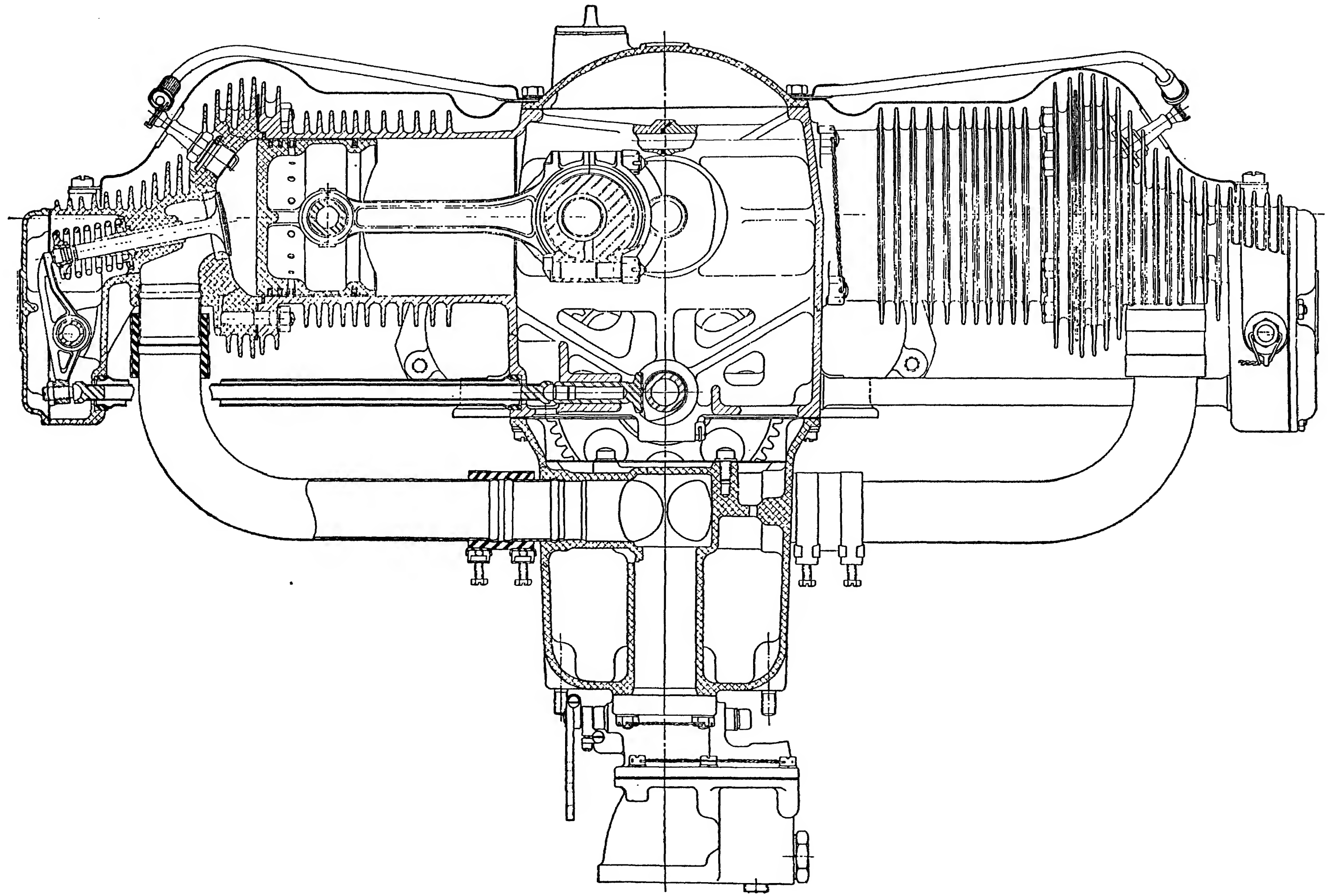


Fig. 8–1. Transverse Section, Lycoming Model 0–145–A1, A2 and A3 Aviation Engines.
(*Lycoming Division, Aviation Manufacturing Corporation.*)

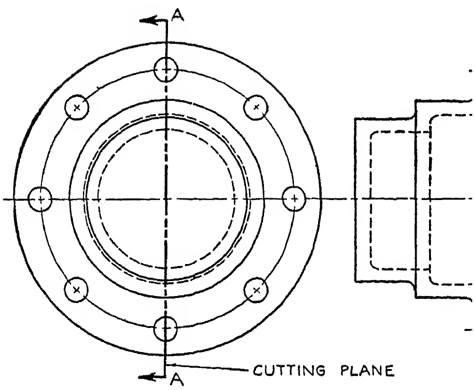


Fig. 8–2. The Exterior Views.

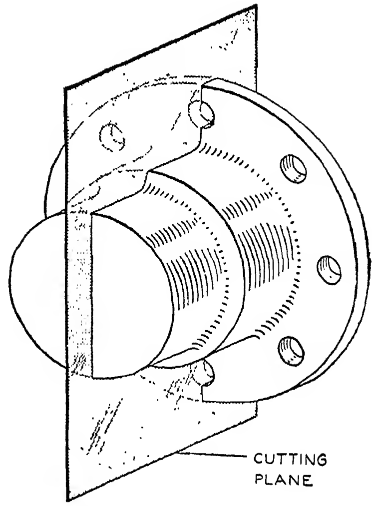


Fig. 8–3. The " Cutting " Plane.

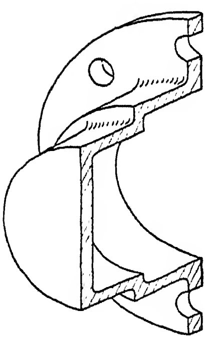


Fig. 8–4. The Front Part Removed.

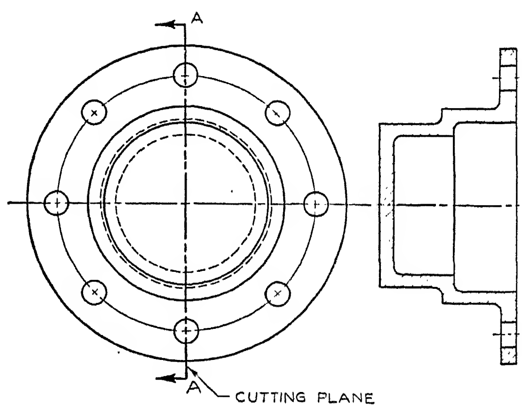


Fig. 8–5. A Sectional View.

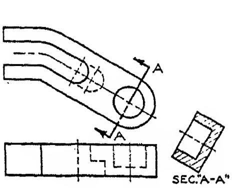


Fig. 8–6.

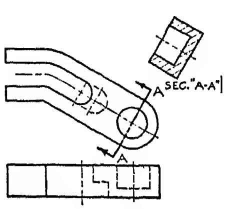


Fig. 8–7.

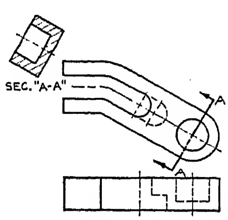


Fig. 8–8.

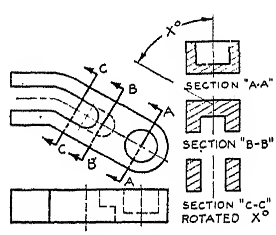


Fig. 8–9.

notation is important on large drawings where the section may be far removed from the cutting plane.

8–5. Symbolic Section Lining. — " Cut " surfaces are generally represented by light full lines, equally spaced and drawn at an angle of 45°. Other angles (30° or 60°) may be used when the plane cuts through a number of different parts. The spacing varies from 1/32 inch to 1/8 + inch according to the area of the cut surface. Thin plate sections may be " blacked-in " solid or " grayed " with the pencil if sectioned.

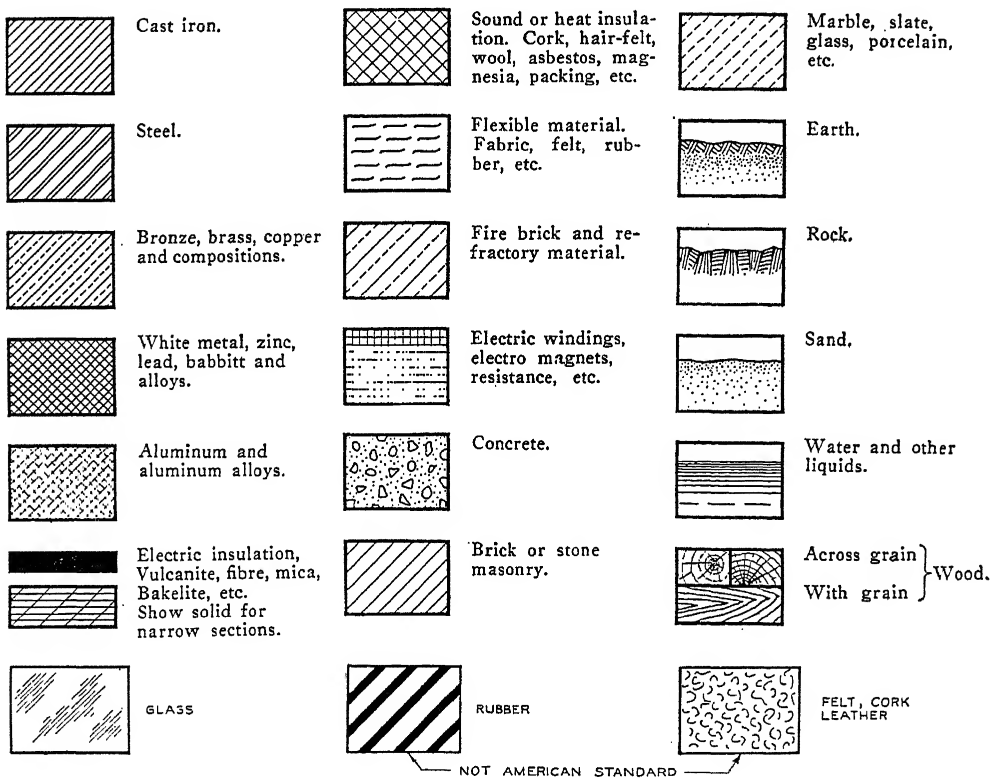


Fig. 8–10. American Standard Symbols for Section Lining.

The American Standard symbols, Fig. 8–10, may be used to indicate different materials or represent different parts. The character of the sectioning should not be depended upon to specify the material. Reference letters and notes should be given to specify the material, treatment, etc. All cut surfaces of any given part must be represented by the same symbol — kind and direction of lines, spacing of lines, etc.

8–6. Kinds of Sectional Views. — The two principal kinds of sections are the full section, Fig. 8–5, where the plane cuts all the way through, and the half

section, Fig. 8–11, where the plane cuts half way through (removing one-fourth of the piece). Note that a half exterior and half section are shown.

Cutting planes may be taken in any position necessary to show the desired section or sections. A non-continuous (staggered or offset) section is shown in

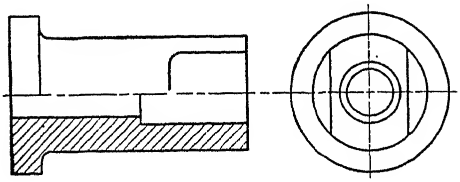


Fig. 8–11. Half Section.

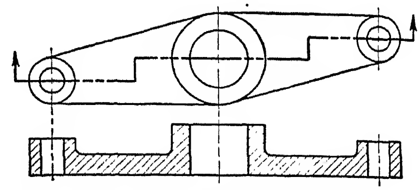


Fig. 8–12. Non-Continuous Section.

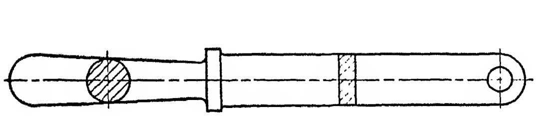


Fig. 8–13. Revolved Section.

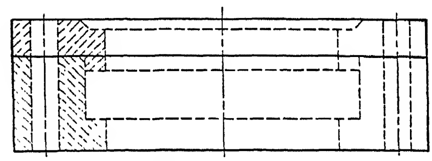


Fig. 8–14. Phantom Section.

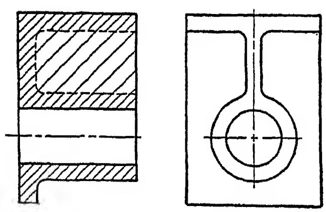


Fig. 8–15. Alternate Sectioning

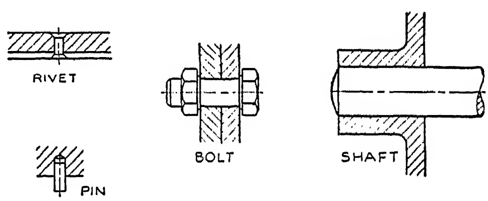


Fig. 8–16. Parts not Sectioned.

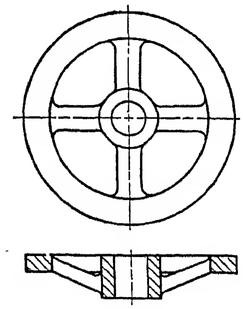


Fig. 8–17. Pulley Arms.

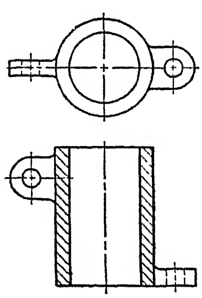


Fig. 8–18.
Conventional Treatment.

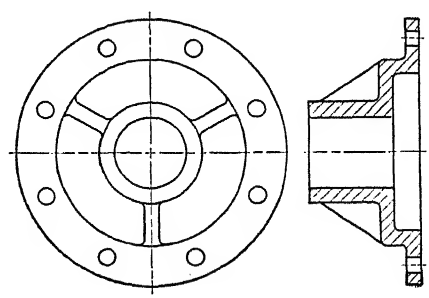


Fig. 8–19.
Conventional Treatment.

Fig. 8–12. "Set in" or "revolved" sections, Fig. 8–13, are used to show the cross sections of rods, tubes, links, etc. Phantom or "hidden" sections are used to indicate a partial section "through" an outside view, Fig. 8–14. Alternate or wide sectioning is sometimes used to indicate a rib, Fig. 8–15.

8–7. Special Treatments of Sections. — There are many details and small parts which are shown more clearly when not sectioned, when the axes are in the cutting plane (Fig. 8–16), such as shafts, bolts, screws, rivets, pins, ribs, pulley arms, and balls and rollers in bearings.

Pulley arms and similar spaced elements are represented as in Fig. 8–17, in which the arms are not sectioned. A " true " section would give a false idea of solidity. Similar conventional treatments of sectional views are shown in Figs. 8–18 and 8–19, which give a clearer description than would be obtained by " true " sections.

Various other uses of sectional views will be observed as they are used on the drawings shown in the illustrations and problems.

8–8. PROBLEMS. — Read Art. 2–16 before starting these problems. Many of these problems are planned for one-quarter of a four-part layout (Fig. 2–31).

Probs. 8–1 to 8–13. Figs. 8–20 to 8–32. — Draw two views and show proper view in section or half section as assigned. All vertical dimensions are diameters.

Probs. 8–14 to 8–19. Figs. 8–33 to 8–38. — Draw the necessary views and show the proper view in section.

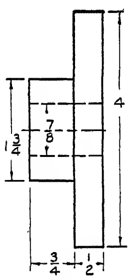


FIG. 8–20. Prob. 8–1.

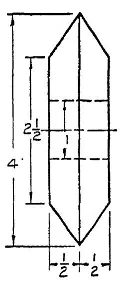


FIG. 8–21. Prob. 8–2.

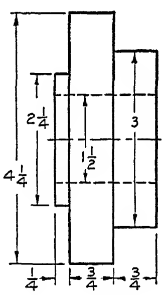


FIG. 8–22. Prob. 8–3.

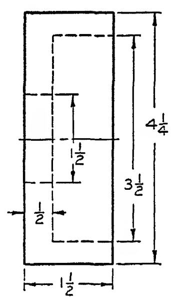


FIG. 8–23. Prob. 8–4.

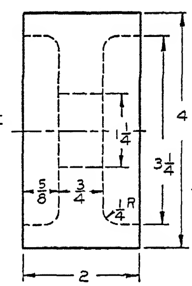


FIG. 8–24. Prob. 8–5.

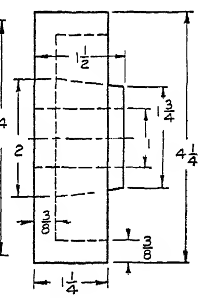


FIG. 8–25. Prob. 8–6.

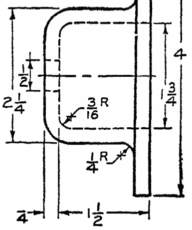


FIG. 8–26. Prob. 8–7.

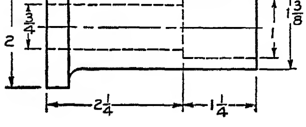


FIG. 8–27. Prob. 8–8.

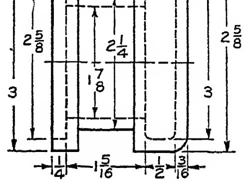


FIG. 8–28. Prob. 8–9.

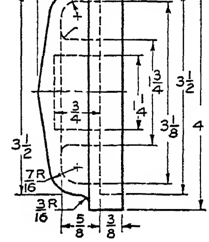


FIG. 8–29. Prob. 8–10.

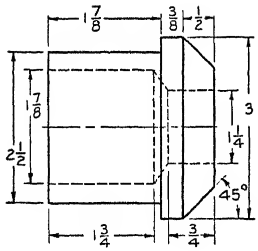


FIG. 8-30.
Prob. 8-11.

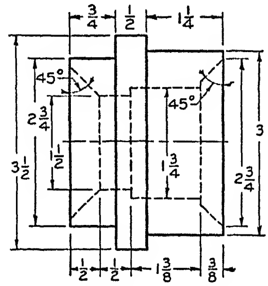


FIG. 8-31.
Prob. 8-12.

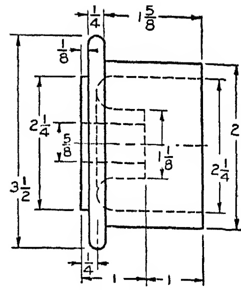


FIG. 8-32.
Prob. 8-13.

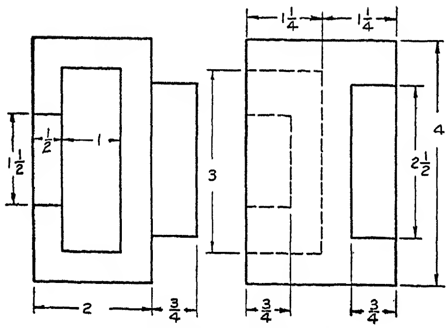


FIG. 8-33. Prob. 8-14.

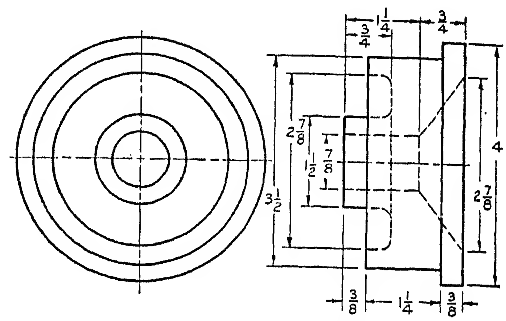


FIG. 8-34. Prob. 8-15.

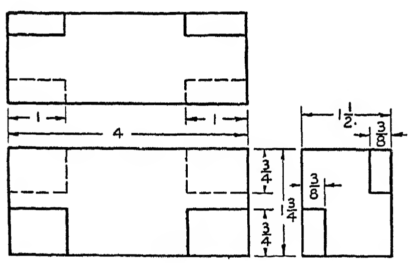


FIG. 8-35. Prob. 8-16.

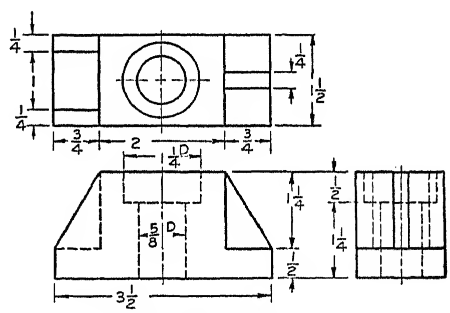


FIG. 8-36. Prob. 8-17.

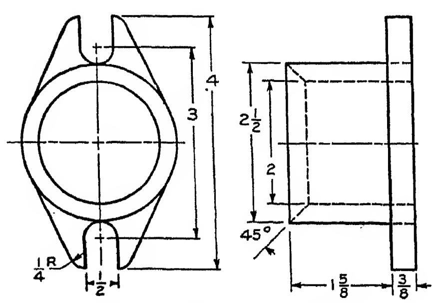


FIG. 8-37. Prob. 8-18.

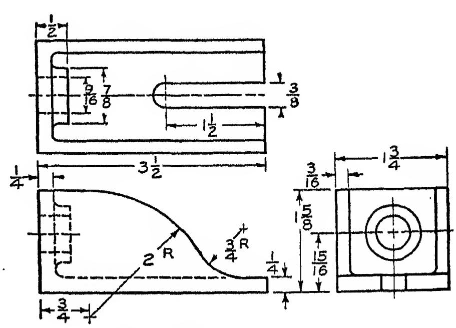


FIG. 8-38. Prob. 8-19.

CHAPTER IX

AIRCRAFT DRAFTING PRACTICE

9–1. Aircraft drafting practice includes certain ways of procedure, representation, reference, and standards which have been found necessary or desirable to meet the requirement of aircraft manufacture. Many features of this practice have a common basis throughout the industry while others vary more or less according to the organization of the particular company. Drafting room manuals, engineering manuals, design standards, etc., are used as a means of insuring uniformity within the organization of a given company.

Army-Navy Standards (Art. 9–14) must be followed on airplanes for the Government and most companies make use of this practice on commercial airplanes.

9–2. Naming of Parts. — Careful thought must be given to the selection of suitable names for parts in order to facilitate such matters as filing, making up parts list, location of the part on the plane, determination of the function of the part, and to avoid general confusion. Standard practice indicates the choice of a noun for the basic word and to place the basic word first followed by a dash and necessary descriptive terms as:

BRACKET — FUEL STRAINER SUPPORT

In the selection of names care should be taken to use similar names for similar parts. Choose a functional, descriptive, and locational title. Choose a basic or key word to be placed on the top line of the name or title block. The second line should be arranged for convenience of identification and filing. Names of details should be related to the name of the assembly. But when a detail is used in more than one place, the name should not be such as to limit interchangeable use. No two parts should be given identical names on any one model. Possibility of confusion may be avoided by the use of such modifying words as: *right, left, upper, lower, center, end, long, short, main,* and *auxiliary.* In the interest of conciseness such words as *and, of, for* etc., should be eliminated.

Examples:

(1) FITTING — TAIL SURFACE HINGE
(Tail Surface Hinge Fitting)

(2) CYLINDER ASSEMBLY — HYDRAULIC FLAP OPERATING
(Hydraulic Flap Operating Cylinder Assembly)

(3) RIB — OUTER PANEL
(Outer Panel Rib)

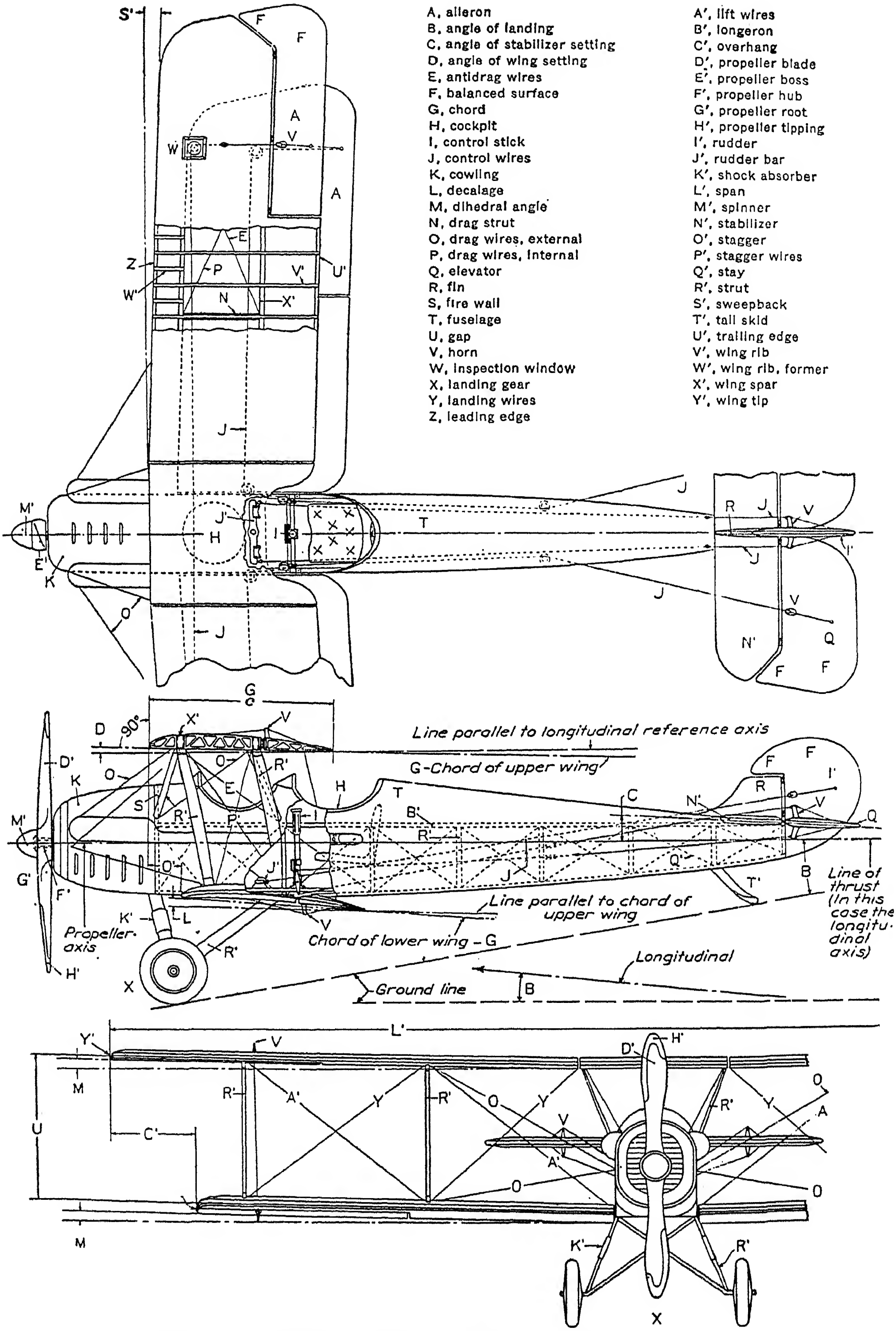


FIG. 9-1. An Airplane. (*National Advisory Committee on Aeronautics.*)

9-3. Nomenclature. — Some definitions which have to do with the parts of aircraft and Figs. 9-1, 9-2, and 9-3 have been selected from the National Advisory Committee for Aeronautics publication "Nomenclature for Aeronautics." This publication is very complete, contains thirty pages of definitions, and several pages of illustrations.

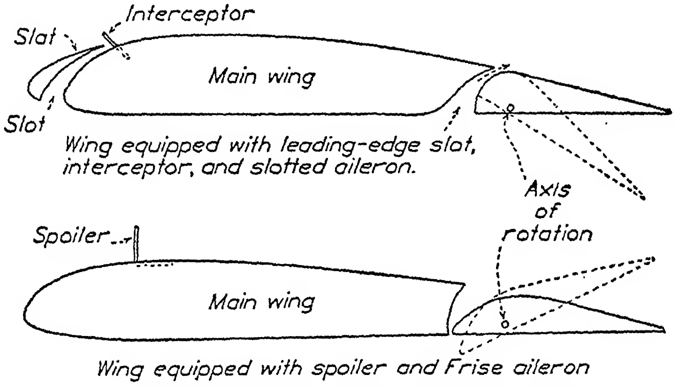


FIG. 9-2. Wing Equipped with Special Control Devices.

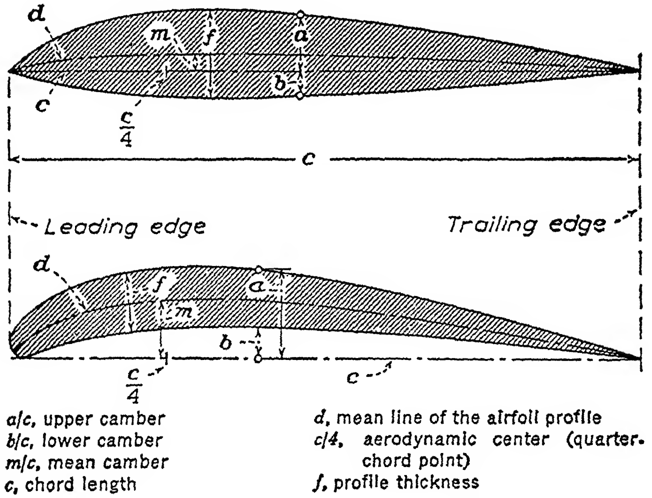


FIG. 9-3. Dimensions of an Airfoil Profile.

aileron — A hinged or movable portion of an airplane wing, the primary function of which is to impress a rolling motion on the airplane. It is usually part of the trailing edge of a wing. (See Fig. 9-1.)

slotted aileron — An aileron having a nose and axis arrangement somewhat similar to a Frise aileron but having a smooth air passage between the nose portion of the aileron and the wing for the purpose of maintaining a smooth air flow over the upper surface of the aileron when its trailing edge is deflected downward. (See Fig. 9-1.)

airfoil — Any surface, such as an airplane wing, aileron, or rudder, designed to obtain reaction from the air through which it moves.

airfoil profile — The outline of an airfoil section (Fig. 9-3).

airfoil section — A cross section of an airfoil parallel to the plane of symmetry or to a specified reference plane.

airplane — A mechanically driven fixed-wing aircraft, heavier than air, which is supported by the dynamic reaction of the air against its wings (Fig. 9–1).

pusher airplane — An airplane with the propeller or propellers aft of the main supporting surfaces.

tractor airplane — An airplane with the propeller or propellers forward of the main supporting surfaces.

air scoop — A scoop or hood designed to catch the air and maintain the air pressure in internal combustion engines, ventilators, etc.

aileron angle — The angular displacement of an aileron from its neutral position. It is positive when the trailing edge of the aileron is below the neutral position.

dihedral angle — The acute angle between a line perpendicular to the plane of symmetry and the projection of the wing axis on a plane perpendicular to the longitudinal axis of the airplane. If the wing axis is not approximately a straight line, the angle is measured from the projection of a line joining the intersection of the wing axis with the plane of symmetry and the aerodynamic center of the half-wing on either side of the plane of symmetry. (See Fig 9–1.)

landing angle — The acute angle between the wing chord and the horizontal when the airplane is resting on level ground in its normal position: also called "ground angle."

angle of attack — The acute angle between a reference line in a body and the line of the relative wind direction projected on a plane containing the reference line and parallel to the plane of symmetry.

angle of incidence — Same as ANGLE OF WING SETTING. In British terminology the angle of incidence is equivalent to the American term "angle of attack."

angle of stabilizer setting — The acute angle between the longitudinal axis of an airplane and the chord of the stabilizer. The angle is positive when the leading edge is higher than the trailing edge. (See Fig. 9–1.)

angle of wing setting — The acute angle between the plane of the wing chord and the longitudinal axis of the airplane. The angle is positive when the leading edge is higher than the trailing edge. (See Fig. 9–1.)

vertical tail area — The area of the actual outline of the rudder and the fin projected in the vertical plane, the fairings and fillets being ignored.

wing area — Wing area is measured from the projection of the actual outline on the plane of the chords, without deduction for area blanketed by fuselage or nacelles. That part of the area, so determined, which lies within the fuselage or nacelles is bounded by two lateral lines that connect the intersections of the leading and trailing edges with the fuselage or nacelle, ignoring fairings and fillets. For the purpose of calculating area, a wing is considered to extend without interruption through the fuselage and nacelles. Unless otherwise stated, wing area always refers to total area including ailerons.

axes of an aircraft — Three fixed lines of reference, usually centroidal and mutually perpendicular. The horizontal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis perpendicular to the other two is called the lateral axis. In mathematical discussions, the first of these axes, drawn from rear to front, is called the X-axis; the second, drawn downward, the Z-axis; and the third, running from left to right, the Y-axis.

biplane — An airplane with two main supporting surfaces placed one above the other.

control cable — The line of wire or stranded cable leading from the control levers to the control surfaces or interconnecting the control surfaces. (See Fig. 9–1.)

camber — The rise of the curve of an airfoil section, usually expressed as the ratio of the departure of the curve from a straight line joining the extremities of the curve to the length of this straight line. "Upper camber" refers to the upper surface; "lower camber" to the lower surface; and "mean camber" to the mean line of section. Camber is positive when the departure is upward, and negative when it is downward. (See Fig. 9–3.)

chord, mean aerodynamic — The chord of an imaginary airfoil which would have force vectors throughout the flight range identical with those of the actual wing or wings.

control stick — The vertical lever by means of which the longitudinal and lateral control surfaces of an airplane are operated. The elevator is operated by a force-and-aft movement of the stick; the ailerons, by a side-to-side movement. (See Fig. 9–1.)

cowling — A removable covering.

cockpit cowling — A metal or plywood cowling placed around a cockpit.

engine cowling — A removable covering placed around all or part of an airplane engine.

decalage — The difference between the angular settings of the wings of a biplane or multiplane. The decalage is measured by the acute angle between the chords in a plane parallel to the plane of symmetry. The decalage is considered positive if the upper wing is set at the larger angle. (See Fig. 9–1.)

drag strut — A fore-and-aft compression member of the internal bracing system of an aircraft. (See Fig. 9–1.)

elevator — A movable auxilary airfoil, the function of which is to impress a pitching moment on the aircraft. It is usually hinged to the stabilizer. (See Figs. 9–1 and 9–2.)

empennage — See TAIL, AIRPLANE.

fairing — An auxiliary member or structure whose primary function is to reduce the drag of the part to which it is fitted.

fin — A fixed or adjustable airfoil, attached to an aircraft approximately parallel to the plane of symmetry, to afford directional stability; for example, tail fin, skid fin, etc. (See Figs. 9–1 and 9–2.)

fitting — A generic term for any small part used in the structure of an airplane or airship. If without qualification, a metal part is usually understood. It may refer to other parts, such as fabric fittings.

flap — A hinged or pivoted airfoil forming the rear portion of an airfoil, used to vary the effective camber.

split flap — A hinged plate forming the rear upper or lower portion of an airfoil. The lower portion may be deflected downward to give increased lift and drag; the upper portion may be raised over a portion of the wing for the purpose of later control (cf. upper-surface aileron).

fuselage — The body, of approximately streamline form, to which the wings and tail unit of an airplane are attached. (See Fig. 9–1.)

gap — The distance separating two adjacent wings of a multiplane. (See Fig. 9–1.)

horn — A short lever attached to a control surface of an aircraft, to which the operating wire or rod is connected. (See Fig. 9–1.)

hydrofoil (or hydrovane) — Any surface designed to obtain reaction from the water through which it moves.

intake header — A short duct extending from outside the engine cowling to the supercharger intake.

landing gear — The understructure which supports the weight of an aircraft when in contact with the land or water and which usually contains a mechanism for reducing the shock of landing. Also called "undercarriage." (See Fig. 9–2.)

leading edge — The foremost edge of an airfoil or propeller blade.

longeron — A principal longitudinal member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support. (See Fig. 9–1.)

monoplane — An airplane with but one main supporting surface, sometimes divided into two parts by the fuselage.

high-wing monoplane — A monoplane in which the wing is located at, or near, the top of the fuselage.

low-wing monoplane —A monoplane in which the wing is located at, or near, the bottom of the fuselage.

midwing monoplane — A monoplane in which the wing is located approximately midway between the top and bottom of the fuselage.

parasol monoplane — A monoplane in which the wing is above the fuselage.

nacelle — An enclosed shelter for personnel or for a power plant. A nacelle is usually shorter than a fuselage, and does not carry the tail unit.

oleo gear — A type of oil-damping device that depends on the flow of oil through an orifice for its shock-absorbing effect in a landing gear.

over-all length — The distance from the extreme front to the extreme rear of an air-

craft, including the propeller and the tail unit.

overhang — (1) One-half the difference in span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (See Fig. 9-1.) (2) The distance from the outer strut attachment to the tip of a wing.

plan form, developed — The plan of an airfoil as drawn with the chord lines at each section rotated about the airfoil axis into a plane parallel to the plane of projection and with the airfoil axis rotated or developed and projected into the plane of projection.

plan form, projected — The contour as viewed from above.

propeller — Any device for propelling a craft through a fluid, such as water or air; especially a device having blades which, when mounted on a power-driven shaft, produce a thrust by their action on the fluid.

propeller root — That part of the propeller blade near the hub. (See Fig. 9-1.)

rudder — A hinged or movable auxiliary airfoil on an aircraft, the function of which is to impress a yawing moment on the aircraft. (See Fig. 9-1.)

rudder bar — The foot bar by means of which the control cables leading to the rudder are operated. (See Fig. 9-1.)

rudder pedals — The foot pedals by means of which the controls leading to the rudder are operated.

slot — The nozzle-shaped passage through a wing whose primary object is to improve the flow conditions at high angles of attack. It is usually near the leading edge and formed by a main and an auxiliary airfoil, or slat. (See Fig. 9-2.) (Cf. slat.)

span — The maximum distance, measured parallel to the lateral axis, from tip to tip of an airfoil, of an airplane wing inclusive of ailerons, or of a stabilizer inclusive of elevator. (See Fig. 9-1.)

spinner — A fairing of approximately conical or paraboloidal shape, which is fitted coaxially with the propeller hub and revolves with the propeller. (See Fig. 9-1.)

stabilizer (airplane) — Any airfoil whose primary function is to increase the stability of an aircraft. It usually refers to the fixed horizontal tail surface of an airplane, as distinguished from the fixed vertical surface. (See Fig. 9-1.)

streamline form — The form of a body so shaped that the flow about it tends to be a streamline flow.

strut — A compression member of a truss frame. (See Fig. 9-1.)

supercharger — A pump for supplying the engine with a greater weight of air or mixture than would normally be inducted at the prevailing atmospheric pressure.

tab — An auxiliary airfoil attached to a control surface for the purpose of reducing the control force or trimming the aircraft.

tail, airplane — The rear part of an airplane, usually consisting of a group of stabilizing planes, or fins, to which are attached certain controlling surfaces such as elevators and rudders; also called "empennage."

trailing edge — The rearmost edge of an airfoil or of a propeller blade.

wheel, tail — A wheel used to support the tail of an airplane when on the ground. It may be steerable or nonsteerable, fixed or swiveling.

wing — A general term applied to the airfoil, or one of the airfoils, designed to develop a major part of the lift of a heavier-than-air craft.

wing profile — The outline of a wing section.

wing rib — A chord-wise member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars.

compression wing rib — A heavy rib designed to perform the function of an ordinary wing rib and also to act as a strut opposing the pull of the wires in the internal drag truss.

former (or false) wing rib. — An incomplete rib, frequently consisting only of a strip of wood extending from the leading edge to the front spar, which is used to assist in maintaining the form of the wing where the curvature of the airfoil section is sharpest. (See Fig. 9-1.)

wing section — A cross section of a wing parallel to the plane of symmetry or to a specified reference plane.

wing spar — A principal span-wise member of the wing structure of an airplane. (See Fig. 9-1.)

9–4. Abbreviations are sometimes necessary on drawings and in such cases uniformity is essential. The following list represents standard practice.

Where more than one abbreviation is indicated the preference of the individual company should be ascertained and the others crossed out.

Abbreviations are undesirable in titles but may have to be used when space does not permit the complete title. Certain group abbreviations are indicated as acceptable.

GROUP ABBREVIATIONS

Armament	ARM.
Center Section	C.S.
Controls	CONT.
Electrical	ELECT.
Empennage	EMP.
Equipment	EQUIP.
Fuselage	FUS.
Hydraulic	HYD.
Landing Gear	LDG. GR. or L.G.
Plumbing	PLUMG.
Power Plant	P.P.
Wing	WING

MISCELLANEOUS ABBREVIATIONS

Absolute Ceiling	A/C
Accessory	ACCES.
Actuating	ACT.
Adjusting	ADJ. or ADJ'G
Adjustment	ADJ. or ADJ'T
Aileron	AIL.
Air Corps	A.C.
Alclad	ALC.
Altitude	ALT.
Aluminum	ALUM.
Aluminum Alloy	AL. ALLOY
Ammunition	AMM.
Ampere	AMP.
Antenna	ANT.
Approximate	APPROX.
Armament	ARM.
Army & Navy	AN
Arresting	ARREST.
Assembly	ASSEM.
Assistant	ASST. or ASS'T
Attached	ATT.
Attaching	ATTACH'G
Attachment	ATT. or ATTACH'T
Auxiliary	AUX.
	BAG.
Balance	BAL.
Battery	BAT.
Bearing	BRG. or BRNG.
Bill of Material	B/M
Bracket	BRKT.
Brazier Head	BR. HD.
Bulkhead	BLKD.
Bureau of Aeronautics	BUAERO
Bushing	BUSH.
Buttock Line	B.L.
Cadmium	CAD.
Calculate	CALC.
Caliber	CAL.
Cancelled	CAN.
Cantilever	CANTIL.
Carburetor	CARB.
Casting	CSTG.
CENTER	CTR.
Center Line	℄ or C.L.
Center of Buoyancy	C.B.
Center of Gravity	C.G.
Center of Pressure	C.P.
Center Punch	C'PUNCH
Center Section	C.S.
Center to Center	C–C
Centimeter	CM.
Centimeters per Second	CM/SEC.
Chamfer	CHAM.
Change	CHNG.
Chapter	CHAP.
Charge	CHG.
Check	CHK.
Chrome-Molybdenum	C.M.
Circumference	CIRCUM.
Command	COMD.
Commercial	COML.
Compartment	COMPT.
Compensating	COMPEN.
Complete	COMPL.
Compression	COMPR.
Condition	COND.
Conduit	COND.
Connecting	CON. or CON'G
Connection	CON.
Contract	CONT. or CONTR.
Control	CONT.
Corrosion	CORR.
Corrugated	CORR. or CORRUG'D
Corrugation	CORR. or CORRUG'N
Counterdrill	C'DRILL
Countersink	CSK or C'SINK
Countersunk	CSK or C'SUNK
Coupling	COUPL. or CPLG.
Covered	COV.
Covering	COV.
Cowling	Do not abbreviate
Cubic Centimeters	C.C.
Cubic Feet	CU. FT.
Cubic Meters	CU. M.
Cylinder	CYL.
Department	DEPT.
Design	DES.
Design Handbook	D.H.
Designation	DESIG.
Desired Loose Fit	DES. L.
Desired Tight Fit	DES. T.
Developed Length	D.L.
Developed Width	D.W.
Diagonal	DIAG.
Diagram	DIAG.
Diameter	DIA.
Differential	DIFF.

Dimension.......DIM.
Direction Finder.........D/F
Disconnect......DISCONT.
Disconnecting....DISCONT.
Distribution.....DISTR.
Distributor......DISTR.
Ditto...........DO.
Dozen..........DOZ.
Draftsman.......DFTSMN.
Drafting........DFTG.
Drafting Room Manual.......D.R.M.
Drawing........DWG.
Each...........EA.
Effective........EFF.
Electrical.......ELECT.
Elevator........ELEV.
Emergence......EMER.
Empennage......EMP.
Enclosure.......ENCL.
Engine..........ENG.
Engineering......ENG.
Equipment......EQUIP.
Equivalent......EQUIV.
Exhaust ....EXH.
Experimental....EXP.
Extinguisher.....EXT.
Extrusion.......EXTR.
Fairing.........FAIR.
Federal.........FED.
Feet...........FT.
Feet per Minute..FT/MIN.
Fillet...........FIL.
Fillister Head....FIL. HD.
Fitting.........FIT.
Flat Head.......F.H. or FL. HD.
Flexible.........FLEX.
Flotation........FLOT.
Forward........FORWD. or FWD.
Frequency.......FREQ.
Fuselage........FUS.
Gallons.........GALS.
Gauge..........GA.
General.........GENL.
Generator.......GEN.
Handbook.......HNDBK.
Hardware.......HDWE.
Head...........HD.
Heat Treat......H.T.
Holder..........HLDR.
Horizontal.......HOR.
Horse Power.....HP.
Hour...........HR.
Hydraulic.......HYD.
Identification....IDENT.
Ignition.........IGN.
Inboard.........INBD.
Inches..........IN.
Indicator........IND.
Information.....INFO.
Inside Diameter..I.D.
Inspection.......INSP.
Inspector of Naval Aircraft.......I.N.A.
Installation......INSTAL.
Instruction......INST. or INSTR.
Instrument......INST.
Instrument Panel.INST. PANEL
Interchangeable..INTCHG.
Interior.........INT.
Intermediate.....INTER. or INTERM.
Junction........JUNCT.
Kilograms.......KG
Kilograms per Sq. Centimeter....KG/SQ.CM.
Kilometers.......KM
Kilometers per Hour.........K.P.H.
Landing.........LDG.
Landing Gear....LDG. GR.
Leading Edge....L.E.
Left Hand.......L.H.
Length..........LENG. or LGTH.
Lightening......LTNG.
Longeron.......LONG.
Longitudinal.....LONG. or LONGT.
Lubricating......LUB. or LUBG.
Lubrication......LUB. or LUBN.
Machine........MACH.
Magneto........MAG.
Magnesium......MAG.
Maintenance.....MAIN or MAINT.
Manufacture.....MFG.
Manufacturer....MFGR.
Material.........MTL. or MATL.
Maximum.......MAX.
Maximum Loose Fit...........MAX. L.
Maximum Tight Fit...........MAX. T.
Mean Aerodynamic Chord........M.A.C.
Mechanical......MECH.
Mechanism......MECH.
Meters..........M.
Miles...........MI.
Miles per Hour...M.P.H.
Millimeters......MM.
Minimum.......MIN.
Minimum Loose Fit...........MIN. L.
Minimum Tight Fit...........MIN. T.
Minutes.........MIN.
Miscellaneous....MISC.
Mixture.........MIXT.
Model..........MOD.
Mold...........M.T.
Molding........M.T.G.
Mold Line.......M.L.
Mount..........MT.
Mounting.......MTG.
Nacelle..........NAC.
National........NATL.
Naval Aircraft Factory.......N.A.F.
Number.........NO.
Number Required......NO. REQ.
Observation.....OBS. or OBSN.
Observer........OBS. or OBSR.
Obsolete.........OBS.
Opening.........OPNG.
Operating.......OPER.
Opposite........OPP.
Oscillator ....OSCIL.
Outboard........OUTBD.
Outside Diameter......O.D.
Parachute Flare..PARA. FLARE
Passenger.......PAS.
Patent..........PAT.
Pattern.........PATT.
Permanent......PERM.
Piece...........PC.
Pitch Diameter...P. DIA.
Plumbing.......PLUMG.
Position.........POS.
Pounds.........LBS.
Pounds per Horse Power........LBS./HP.
Pounds per Square Foot.........LBS./SQ. FT.

Pounds per Square Inch	P.S.I. or LBS./SQ. IN.
Power Plant	P.P.
Preliminary	PRELIM.
Pressure	PRES. or PRESS.
Production	PROD.
Propeller	PROP.
Pyrotechnics	PYRO.
Radiator	RAD.
Radius	R.
Rear	RR.
Receiver	REC. or REVR.
Receptacle	RECEPT.
Reference	REF.
Reinforcement	REINF. or REINF'T
Reinforcing	REINF. or REINF'G
Release	REL.
Required	REQ.
Requirements	REQMTS.
Retainer	RET.
Retaining	RET. or RETG.
Retracting	RETRG.
Revised	REV. or REV'D
Revision	REV. or REV'N
Revolutions per Minute	R.P.M.
Right Hand	R.H.
Round Head	RD. HD.
Rubbing	RUB.
Rudder	RUD.
Sea Level	S.L. or S/L
Second	SEC.
Section	SEC. or SECT.
Segment	SEG.
Selector	SEL.
Separate	SEP.
Service Ceiling	S/C or SER. CEIL.
Shock Absorber	SH. ABS.
Special	SPEC.
Specification	SPEC.
Spherical	SPHER.
Spherical Radius	SPH. R. or SPHER. R.
Square Feet	SQ. FT.
Square Inches	SQ. IN.
Stabilizer	STAB.
Standard	STD.
Station	STA.
Steel	STL. or ST'L
Stiffener	STIF.
Stock Length	S.L.
Stock Width	S.W.
Structure	STRUC.
Supercharger	SUP. or SUPCHGR. or SUPCHG.
Superseded	SUP'D
Support	SUP. or SUP'T
Supporting	SUP. or SUP'G
Symmetrical	SYM.
Synchronize	SYNC. or SYNCHR.
System	SYST.
Tachometer	TACH.
Temperature	TEMP.
Terminal	TERM.
Thread	THD.
Thrust Line	T.L.
Trailing Edge	T.E.
Transformer	TRANSF.
Transmitter	TRANSM.
Transverse	TRANSV.
Ultimate	ULT.
Ultra High Frequency	U.H.F.
Vertical	VERT.
Water Line	W.L.
Wind Tunnel Model	W.T.M.
Wing	WING

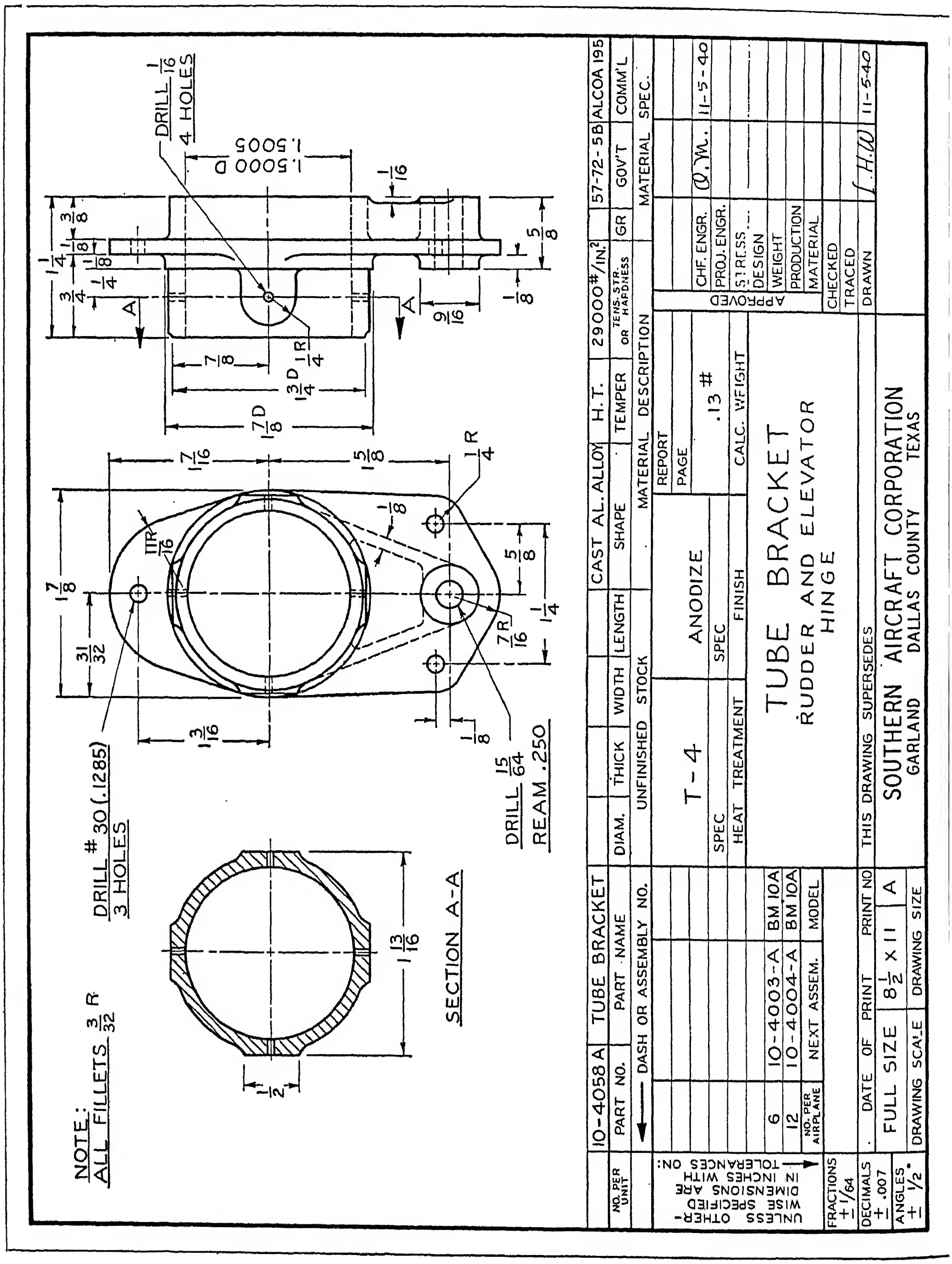
9–5. Types of Drawings. — Drawings are classified in general terms as detail drawings and assembly drawings. A detail drawing gives all information for a single piece, and may be for a casting, forging, sheet metal part, etc. Detail drawings are illustrated in Figs. 9–4 and 9–5. An assembly drawing may include all the parts or a group of parts. Assembly drawings are of many kinds according to the purpose for which they are made as: sub-assembly drawing, made for a group of parts, layout assembly, outline assembly, sectional assembly, installation assembly, etc.

9–6. Sizes of Drawings. — The basic size is $8\frac{1}{2}'' \times 11''$. Most larger sizes are multiples of this size to facilitate folding and filing.

The sizes of drawings are given in Fig. 9–6 which is reproduced from the Drafting Room Manual of North American Aviation, Inc.

9–7. Scale of Drawings. — The following quotation from the Drafting Room Manual of North American Aviation, Inc., describes general practice in regard to the choice of scales and the use of scales on aircraft drawings.

"As a general rule, drawings will be made actual size. These drawings are to be drawn to scale within $\frac{1}{32}$ of an inch. Drawings which are badly out of scale are to be corrected or redrawn.


NOTE: ALL FILLETS 3/32 R
DRILL #30 (.1285) 3 HOLES
SECTION A-A
DRILL 15/64 REAM .250
DRILL 1/16 4 HOLES
1.5000 D
1.5005
10-4058 A TUBE BRACKET
PART NO. PART NAME
DASH OR ASSEMBLY NO.
CAST AL. ALLOY H.T. 29000#/IN.² 57-72-5B ALCOA 195
DIAM. THICK WIDTH LENGTH SHAPE TEMPER TENS. STR. OR HARDNESS GR GOV'T COMM'L
UNFINISHED STOCK MATERIAL DESCRIPTION MATERIAL SPEC.
T-4
HEAT TREATMENT SPEC
ANODIZE
FINISH SPEC
REPORT PAGE
.13 #
CALC. WEIGHT
TUBE BRACKET
RUDDER AND ELEVATOR HINGE
6 10-4003-A BM 10A
12 10-4004-A BM 10A
NO. PER AIRPLANE NEXT ASSEM. MODEL
NO. PER UNIT
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES WITH TOLERANCES ON:
FRACTIONS ± 1/64
DECIMALS ± .007
ANGLES ± 1/2°
CHF. ENGR. PROJ. ENGR. STRESS DESIGN WEIGHT PRODUCTION MATERIAL
APPROVED
11-5-40
CHECKED TRACED DRAWN
11-5-40
DATE OF PRINT PRINT NO
FULL SIZE 8 1/2 x 11 A
DRAWING SCALE DRAWING SIZE
THIS DRAWING SUPERSEDES
SOUTHERN AIRCRAFT CORPORATION
GARLAND DALLAS COUNTY TEXAS

" Draftsmen should bear in mind that the primary object in reducing the scale of a drawing is to reduce the size of the sheet; therefore, as small a sheet as possible, without crowding the drawing, should be used. The preferred scales are actual 2, 4, ½, ¼, and ⅛ sizes. Enlarged drawings, views, or sections will be made when the actual size is so small or so crowded that the drawing is not clear. Reduced scale of drawings will be made of large parts that can be shown clearly in the smaller scale.

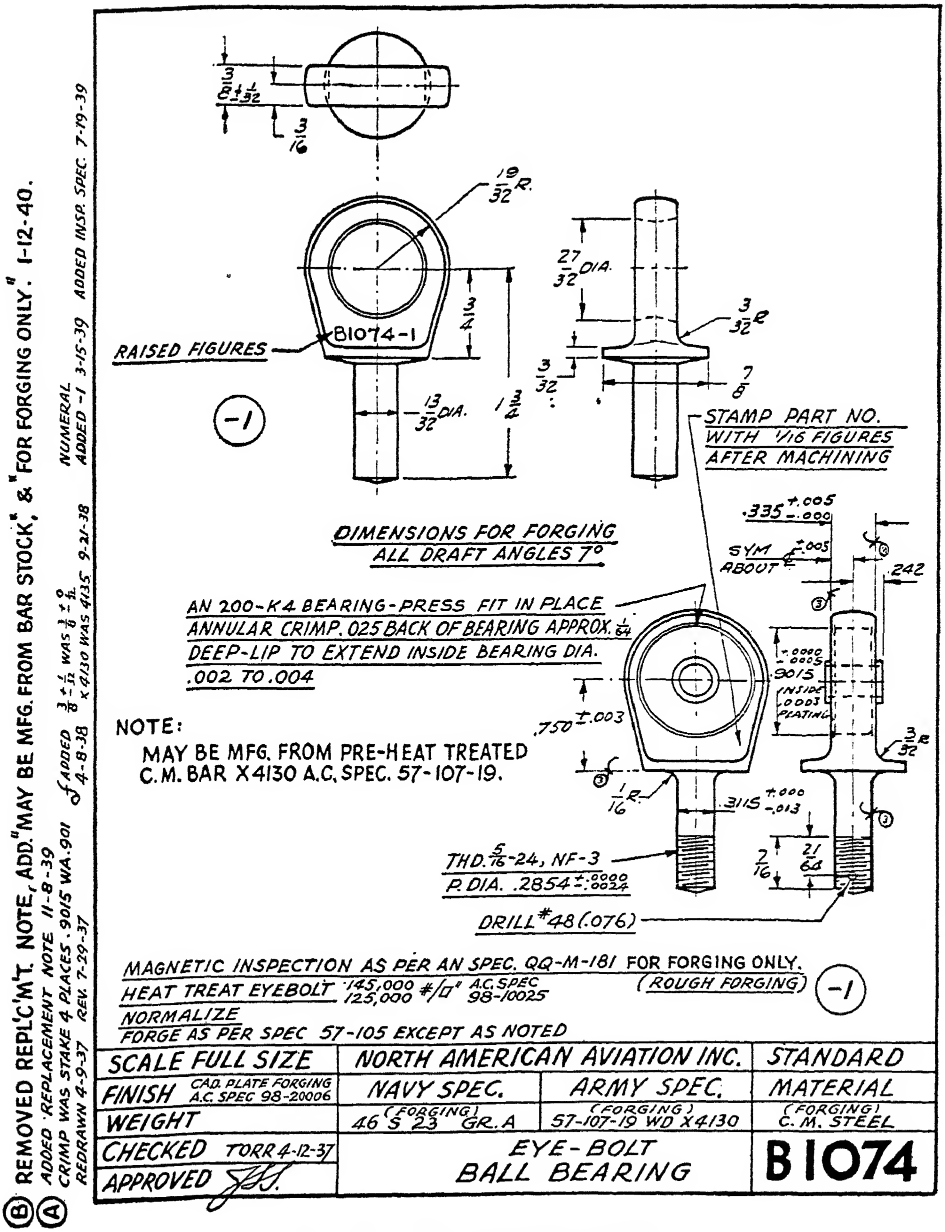
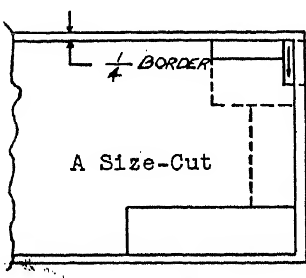


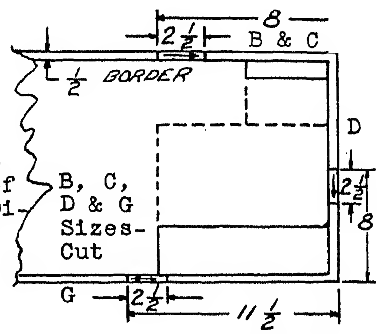
FIG. 9–5. Detail Drawing (Forging)

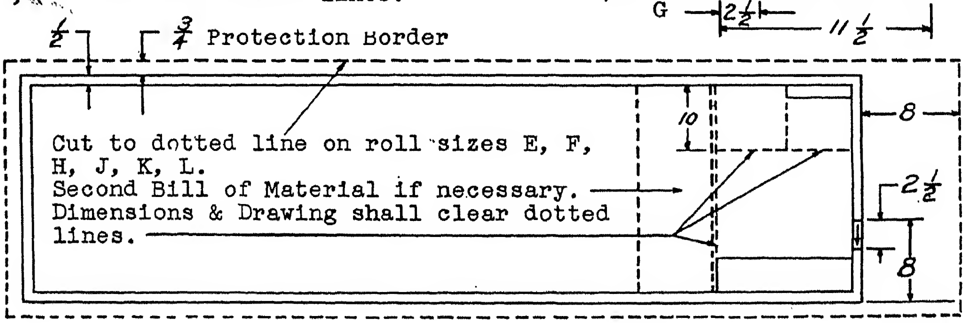
SIZE OF DRAWINGS

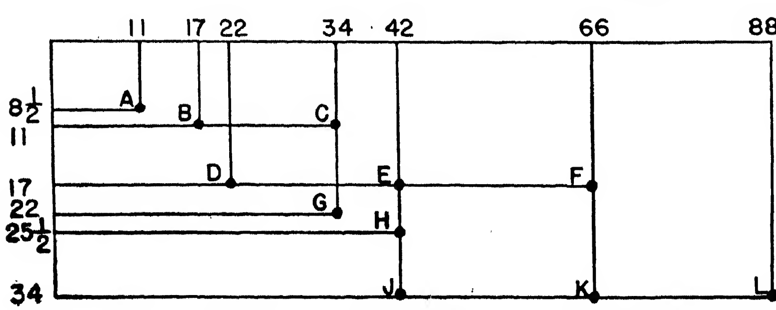
All drawings are to be made on one of the sizes listed below. On Navy Contracts, which are strictly in accordance with Navy Specifications, the length of the drawing will not exceed 12 feet. The minimum length of all roll size drawings will be 42 inches. When the length of a drawing is not standard, it should be a multiple of 11. (This is necessary in order to facilitate filing). The non-standard sizes are not to be listed in the size square of the Title Block, but the next largest size letter is to be placed there instead. This, of course, applies only to sizes up to L, all others must be listed in order to ascertain the square footage when the drawing is printed. Vellum is obtainable, in cut sizes and in 36 or 21 inch widths, from Engineering Supplies. The 36 and 21 inch vellums are to be used for 34 and 17 inch roll size drawings respectively. The protection border, on roll sizes, will be an additional $1\frac{1}{2}$ inch.



File numbers are to read in direction of arrows as shown. Dimensions & drawing shall clear dotted lines.







Dimensions for roll sizes E, F, H, J, K, L, does not include the protective border.

FIG. 9–6. Sizes of Drawings. (*North American Aviation, Inc.*)

" All drawings must show the scale in the space provided in the Title Block, using notations such as, 'FULL SIZE,' 'TWICE SIZE,' 'HALF SIZE,' 'QUARTER SIZE,' etc. When views and/or sections differing in scale the word 'noted' is to be added in the space provided in the Title Block. In addition, the correct scale is to be shown under each view and/or section which differs in scale from the main drawing.

" When enlarged views are depicted, an actual size picture of the part is to be shown, in one view, on the same drawing. In which case, the drawing should include the proper scale notes."

9–8. Point of View. — Layouts, installation, and major assembly drawings are drawn as they would appear in side elevation headed toward the left (Fig. 9–7). Parts are called left- or right-hand as they would be in relation to a seated pilot.

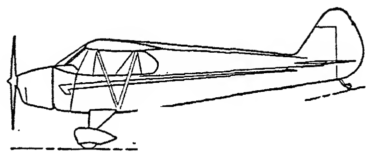


FIG. 9–7. Point of View. (Plane Headed toward the Left.)

Whenever there are left- and right-hand parts, the left-hand parts are drawn and the right-hand parts are called out in a note as:

L.H. SHOWN
R.H. OPPOSITE

or if dash numbers (Art. 9–15) are used:

14025 L.H. SHOWN	or	14025–2 L.H. SHOWN
14025–1 R.H. OPPOSITE		14025–3 R.H. OPPOSITE

Basic numbers or even dash numbers represent L.H. and odd dash numbers represent R.H. parts.

Left- and right-hand parts are distinguished by the reversion of bends or construction about the center line of the part. A part is not considered left- or right-hand simply because it is installed on the left- and right-hand sides of the plane.

The point of view for drawings of such parts as fuselage bulkheads, etc., is from the rear of the airplane. If viewed from the front a note " LOOKING AFT " should be used.

Drawings of sub-assemblies and of details are made with views which will give the best description.

9–9. Symmetry and Center Lines. — Symmetry is indicated on drawings by center lines. Holes, cylindrical parts, etc., have one center line to locate the axis and two intersecting center lines to locate the center of the circular view (Fig. 9–8 at *A* and *B*). A center line drawn through a series of holes is called a pitch line and may be either straight or curved (Fig. 9–8 at *C* and *D*). When it is necessary to call attention to a center line for reference or other purposes, the symbol shown in Fig. 9–9 is used. When a part or assembly is symmetrical, or the same on each side of a center line, one side only may sometimes be drawn — the left-hand side — with the symbol shown in Fig. 9–10.

9–10. Zone marking is often used on large drawings. This means that the sheet is divided into sections or zones by imaginary lines. Zones are generally

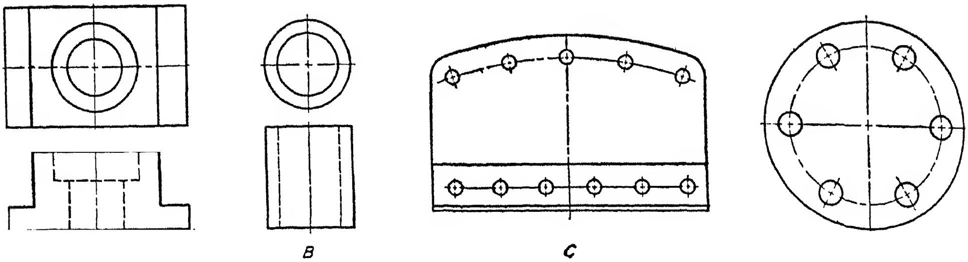


Fig. 9–8. Use of Center Lines.

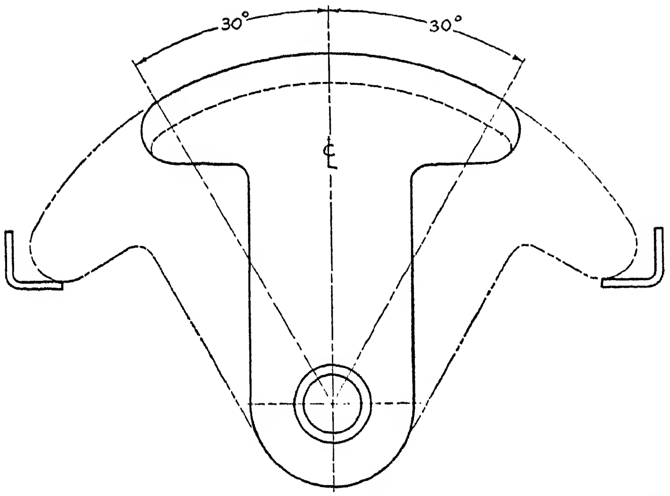


Fig. 9–9. Symbol for Center Line.

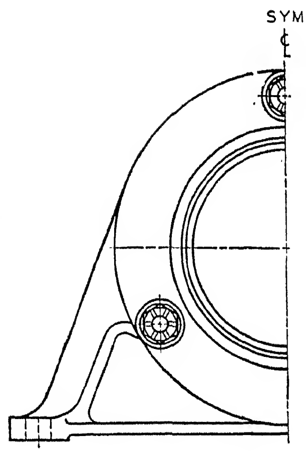


Fig. 9–10. Symbol for Symmetry.

made eleven inches wide and are numbered or lettered from right to left along the lower border line. Items on the drawing can be easily located by reference to the zone number as given in the bill of material.

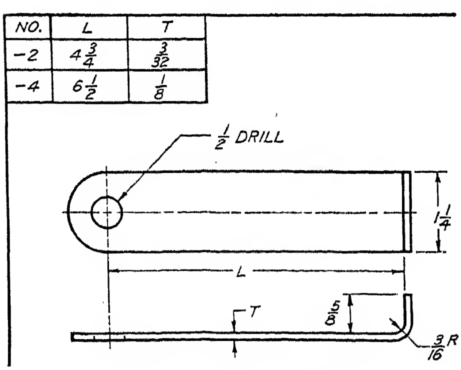


Fig. 9–11. Tabulated Drawing.

9–11. Tabulated drawings are sometimes made for parts which are alike except for certain dimensions which can be indicated by letters and referred to a table of actual dimensions (Fig. 9–11).

9–12. Conventional representations are often used for many items shown on aircraft drawings as illustrated in Figs. 9–12 to 9–15 from the Lockheed Aircraft Corporation Drafting Room Manual and from which the following is quoted.

"In the case of detail drawings, some of these articles such as nuts, screws and bolts may have to show more detail for proper representation. (See Chap. X.)

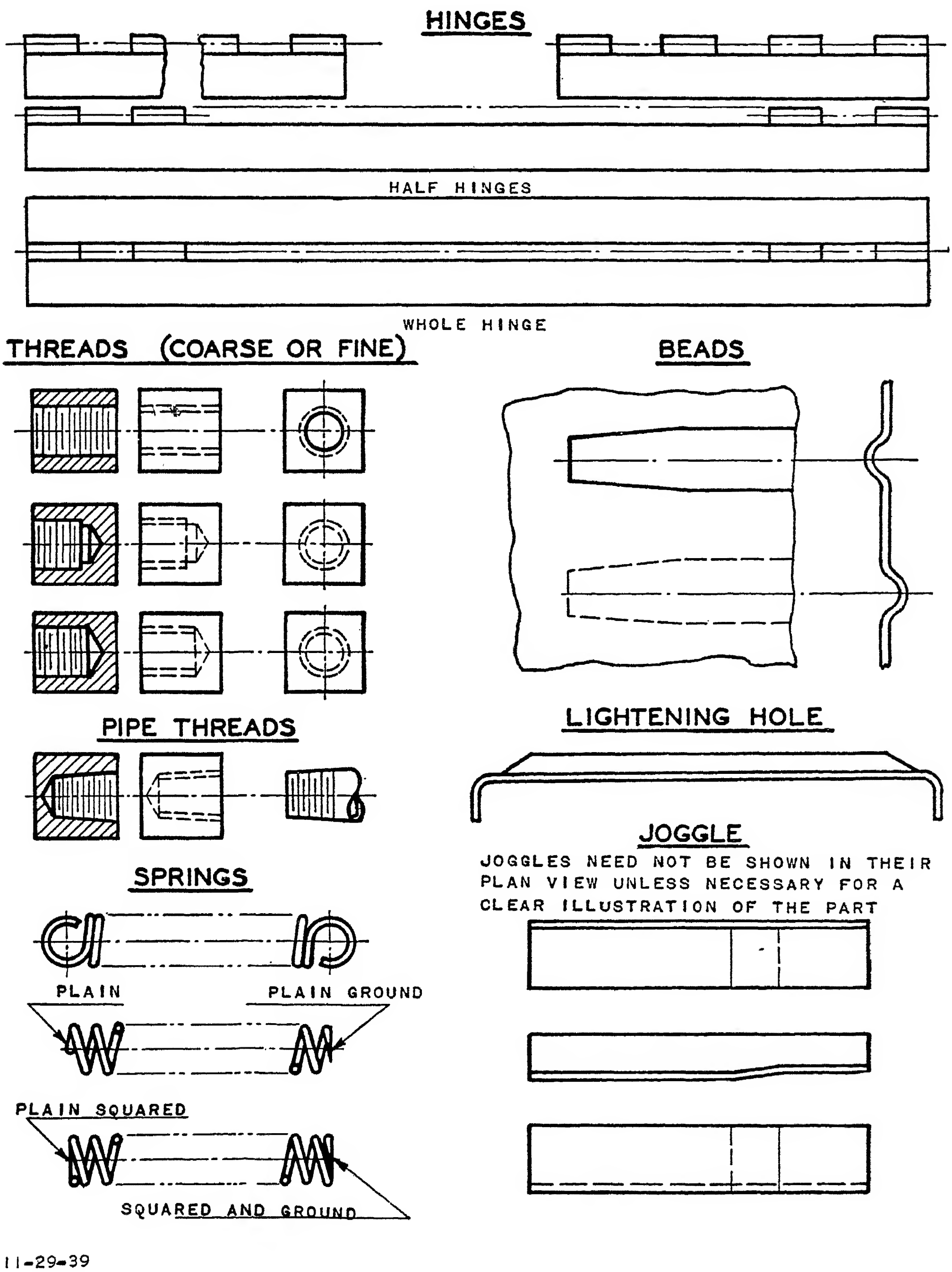


FIG. 9-12. Conventional Representations. (*Lockheed Manual.*)

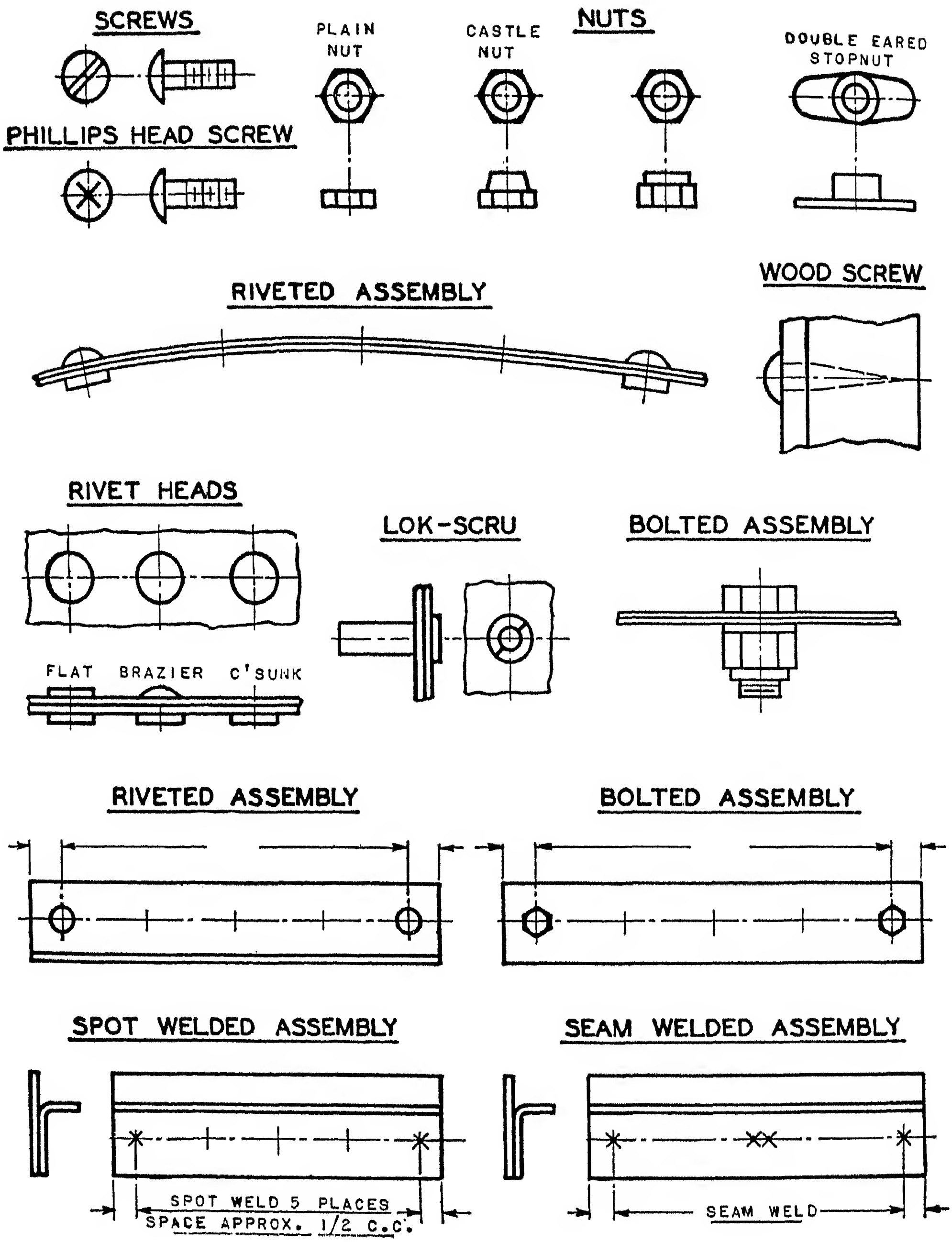


Fig. 9–13. Conventional Representations. (*Lockheed Manual.*)

"It is equally as incorrect to complicate a drawing by including non-essential views and intricate and unnecessary detail, as it is to leave a drawing unfinished. A draftsman is judged on the basis of ability to produce drawings which are complete, but *not* 'over-complete.'

"The conventions shown on the following pages (Figs. 9–13 to 9–15) are intended for use in clarifying drawings and they (and any other labor saving practices) should be utilized whenever possible. For instance, hidden lines should be shown only where their use serves to clarify the drawing. Too many hidden lines on an assembly are confusing and, therefore, are definitely undesirable."

Other conventional representations will be found in Chapters VII and X and on various drawings illustrated throughout this book.

9–13. Standard Parts. — These consist of parts which do not have to be designed for use on any particular plane or part of a plane but which have a general application. Standard parts include bolts and nuts, washers, pins, bushings, ball bearings, keys, many kinds of joints and fastenings, rivets, handles, links, and many parts manufactured for general use.

The AN and AC Standards are described in Art. 9–14. Commercial standards is a general term to describe manufactured parts (other than AN) which are available to all companies. Each company has certain parts which are standard for their own uses and which are " called out " by a company symbol. Other standards including the American Standards Association (ASA) are mentioned in Art. 9–14.

9–14. AN and AC Standards. — For Government work the Army-Navy (AN) Standards must be used. These are standards and specifications for aircraft parts and materials that have been adopted in common by the Government Air Services. They are designated by AN numbers. Such identification numbers are in general use on drawings for commercial aircraft and serve as a means of promoting uniformity of materials and finishes, and interchangeability of parts. Army-Navy specifications and standard parts, are given in books which are available at aircraft and related companies where this information is used and where it can be kept in agreement with revisions as they are made.

Some sample standard sheets are reproduced in Figs. 9–16, 9–17 and 9–18. The lower right-hand corner of the sheet contains a large number which is the major drawing (page) number and major part number. This number followed by a " dash number " (see column headed Dash No.) is used to specify a particular part as indicated by the examples shown on the sample sheets.

A sample design standard sheet is illustrated in Fig. 9–19.

These standards have been developed in various departments of the Government, engineering societies and commercial engineering departments such as the U. S. Army Air Corps (AC), U.S. Navy Bureau of Aeronautics (BUAERO), Naval Aircraft Factory (NAF), American Standards Association (ASA), Society of Automotive Engineers (S.A.E.), American Society for Testing Materials (ASTM), etc. Standards marked AC are for use only by the Air Corps while AN Standards are accepted for use by the Army and Navy. The current AC and AN Standards must be followed on drawings at the time they are prepared.

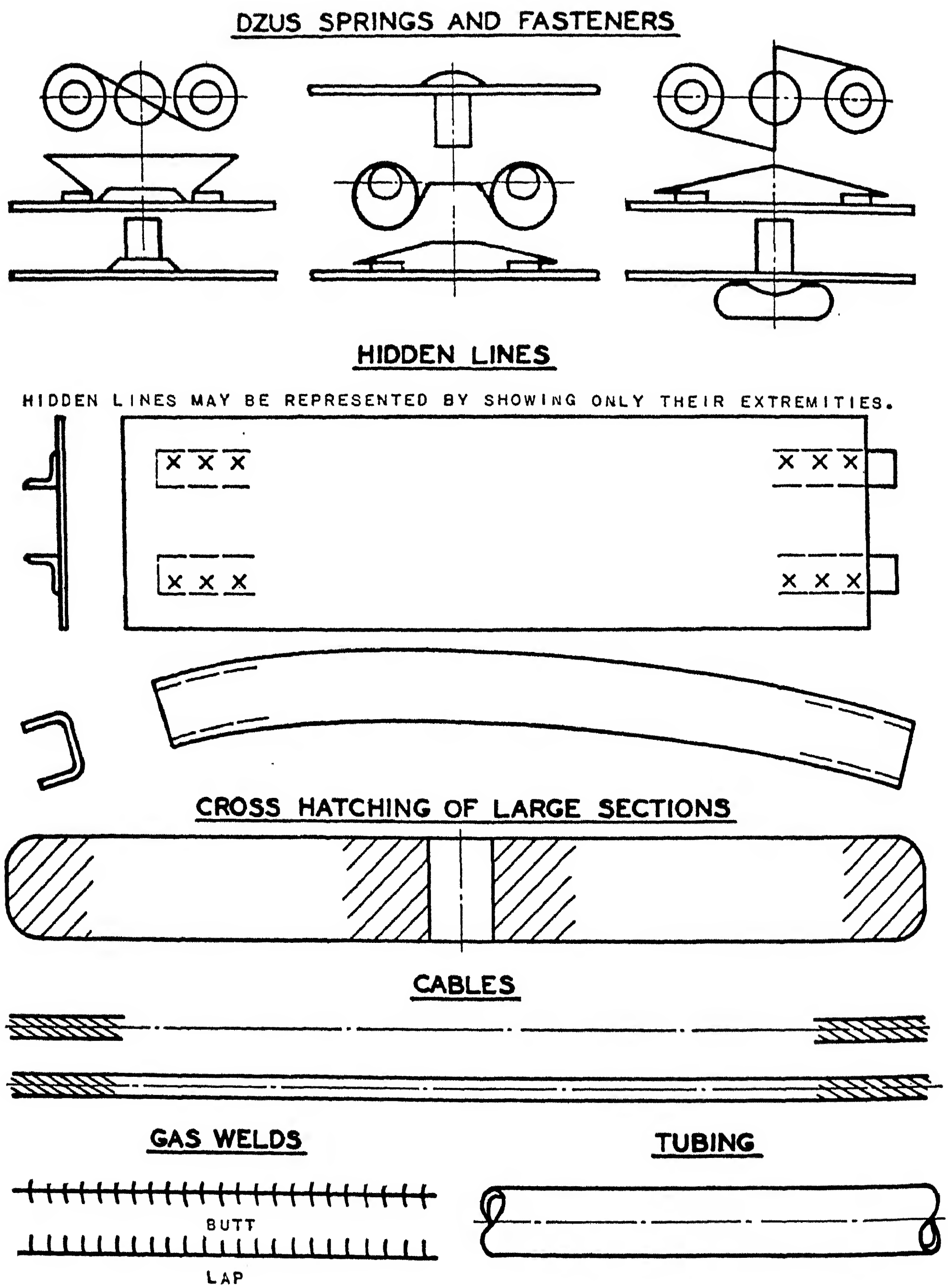


Fig. 9-14. Conventional Representations. (*Lockheed Manual.*)

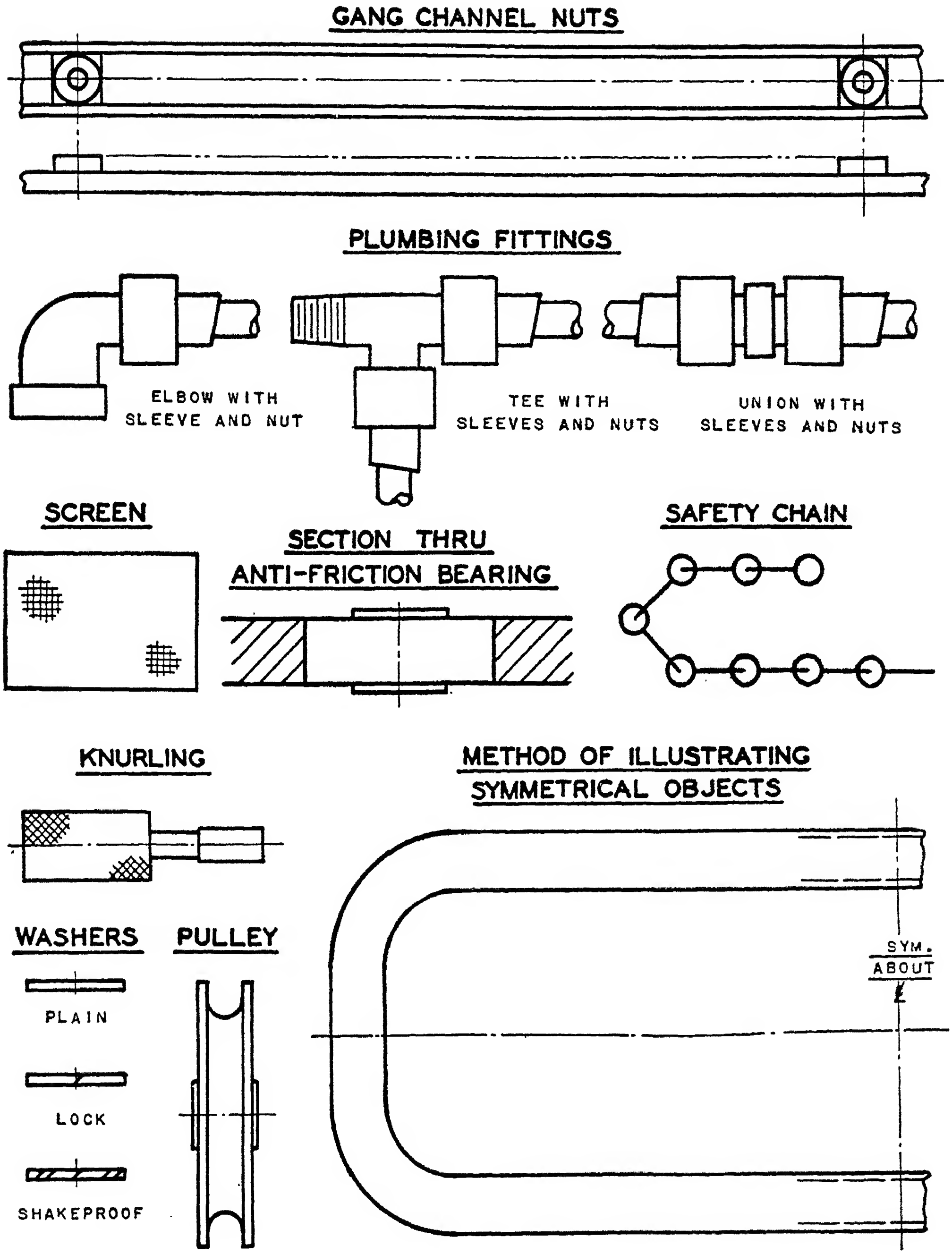
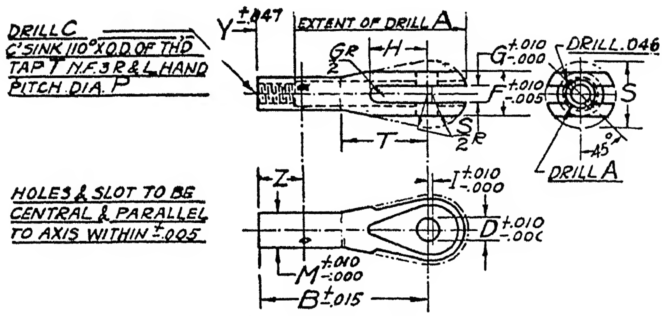


FIG. 9–15. Conventional Representations. (*Lockheed Manual.*)



DASH NOS.	TIE ROD STGTH.	TAP T	PITCH DIA. P	MAX. DRILL C	DRILL A	B	D	F	G	H	I	M	S	T	Y	Z
10L 10R	1200	6-40	$.1218^{+.0017}_{-.0000}$	#33 .1130	.147	$1\frac{5}{16}$	.188	.250	.109	$\frac{3}{8}$	$\frac{1}{32}$	.250	$\frac{3}{8}$	$\frac{5}{8}$	.250 $\frac{1}{4}$	$\frac{5}{16}$
21L 21R	2400	10-32	$.1697^{+.0019}_{-.0000}$	#21 .1590	.199	$1\frac{17}{32}$	.188	.313	.150	$\frac{15}{32}$	$\frac{1}{32}$	.281	$\frac{1}{2}$	$\frac{23}{32}$	.313 $\frac{5}{16}$	$\frac{3}{8}$
34L 34R	4200	$\frac{1}{4}$-28	$.2268^{+.0022}_{-.0000}$	#3 .2130	.261	$1\frac{13}{16}$	.250	.438	.203	$\frac{5}{8}$	$\frac{3}{64}$	.375	$\frac{5}{8}$	$\frac{7}{8}$	.438 $\frac{7}{16}$	$\frac{1}{2}$
46L 46R	⊕4600	$\frac{5}{16}$-24	$.2854^{+.0024}_{-.0000}$	.2703	.323	$1\frac{7}{8}$	.313	.500	.203	$\frac{21}{32}$	$\frac{3}{64}$	.438	$\frac{11}{16}$	$\frac{15}{16}$	.563 $\frac{9}{16}$	$\frac{5}{8}$
61L 61R	6900	$\frac{5}{16}$-24	$.2854^{+.0024}_{-.0000}$	.2703	.323	2	.375	.563	.203	$\frac{27}{32}$	$\frac{1}{16}$	.453	$\frac{3}{4}$	1	.563 $\frac{9}{16}$	$\frac{5}{8}$
80L 80R	10000	$\frac{3}{8}$-24	$.3479^{+.0024}_{-.0000}$	Q .3320	.386	$2\frac{1}{4}$	.375	.563	.266	$\frac{7}{8}$	$\frac{1}{16}$	.547	$\frac{7}{8}$	$1\frac{1}{8}$	.688 $\frac{11}{16}$	$\frac{3}{4}$
115L 115R	13700	$\frac{7}{16}$-20	$.4050^{+.0026}_{-.0000}$	W .3860	.453	$2\frac{1}{2}$	.438	.719	.344	1	$\frac{5}{64}$	.625	$1\frac{1}{16}$	$1\frac{1}{4}$	.750 $\frac{3}{4}$	$\frac{13}{16}$
155L 155R	18500	$\frac{1}{2}$-20	$.4675^{+.0026}_{-.0000}$	.4492	.516	$2\frac{13}{16}$	.500	.813	.406	$1\frac{3}{16}$	$\frac{5}{64}$	.703	$1\frac{3}{16}$	$1\frac{7}{16}$	.875 $\frac{7}{8}$	$\frac{15}{16}$
202L 202R	24000	$\frac{9}{16}$-18	$.5264^{+.0030}_{-.0000}$	.5062	.578	$3\frac{1}{8}$	.563	.922	.453	$1\frac{3}{8}$	$\frac{3}{32}$	.796	$1\frac{3}{8}$	$1\frac{5}{8}$	1	$1\frac{1}{16}$
247L 247R	29500	$\frac{5}{8}$-18	$.5889^{+.0030}_{-.0000}$	.5687	.640	$3\frac{3}{8}$	.625	1.032	.516	$1\frac{1}{2}$	$\frac{3}{32}$	.875	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{3}{16}$
430L 430R	42000	$\frac{3}{4}$-16	$.7094^{+.0032}_{-.0000}$	.6875	.766	$4\frac{1}{8}$	.750	1.250	.656	$1\frac{15}{16}$	$\frac{7}{64}$	1.063	$1\frac{13}{16}$	$2\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$
580L 580R	58000	$\frac{7}{8}$-14	$.8286^{+.0036}_{-.0000}$	.8024	.891	$4\frac{7}{8}$	.875	1.500	.781	$2\frac{5}{16}$	$\frac{7}{64}$	1.250	$2\frac{1}{8}$	$2\frac{11}{16}$	$1\frac{5}{8}$	$1\frac{11}{16}$
760L 760R	76000	1-14	$.9536^{+.0036}_{-.0000}$	.9274	1.016	$5\frac{3}{4}$	1.000	1.750	.906	$2\frac{11}{16}$	$\frac{1}{8}$	1.438	$2\frac{7}{16}$	$3\frac{1}{8}$	$1\frac{7}{8}$	$1\frac{15}{16}$

⊕ SPECIAL FOR USE WITH 6900# ROD WITH 4600# RATING.

EXAMPLE OF PART NUMBER - AN665-10L
AN665-10R

MATERIAL - SPEC. 57-107-17 NICKEL STEEL
HEAT TREAT - 125000# PER SQ. IN. TENSILE STRENGTH MIN.

MANUFACTURING SPEC. 29-21.
LIMITS ON DIMENSIONS ±.010 UNLESS OTHERWISE SPECIFIED.

NOTE: TERMINALS APPROVED BY THE MATERIEL DIVISION AS SUBSTITUTES FOR USE ON ARMY AIRCRAFT SHALL BE SPECIFIED ON AIRCRAFT DRAWINGS BY THE TERMINAL MANUFACTURER'S PART NUMBERS.

* THREADS SHALL BE IN ACCORDANCE WITH SPEC. AN-GGG-S-126. SYMBOL NF-3

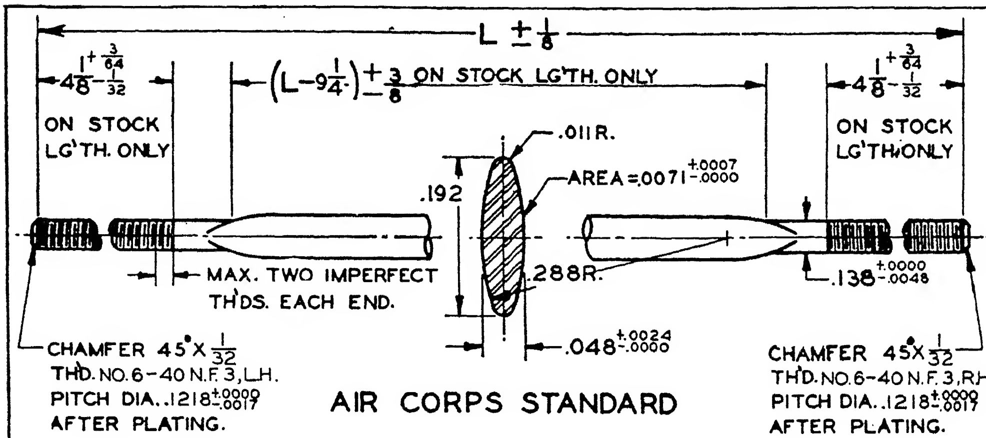
REVISED 6-5-37, 7-1-40

B/M

APPROVED	AIR CORPS STOCK CLASSIFICATION 04-A	ARMY & NAVY STD.
3-22-26	TERMINAL - TIE ROD - THREADED CLEVIS TYPE	AN665

Fig. 9–16.

U. S. ARMY AIR CORPS. MATERIEL DIVISION. DAYTON, OHIO.



L	DASH NO.	L	DASH NO.	L	DASH NO.	L	DASH NO.	L	DASH NO.	L	DASH NO.	L	DASH NO.
18	18	60	60	102	102	144	144	186	186	228	228	270	270
24	24	66	66	108	108	150	150	192	192	234	234	276	276
30	30	72	72	114	114	156	156	198	198	240	240		
36	36	78	78	120	120	162	162	204	204	246	246		
42	42	84	84	126	126	168	168	210	210	252	252		
48	48	90•	90	132	132	174	174	216	216	258	258		
54	54	96	96	138	138	180	180	222	222	264	264		

STANDARD DESIGN OF TIE ROD USED BY THE AIR CORPS FOR REPLACEMENT ON AIRPLANES IN SERVICE.

TABULATION GIVES LENGTHS OF RODS TO BE PURCHASED FOR GENERAL USE. INTERMEDIATE LENGTHS ARE OBTAINED BY CUTTING AN EQUAL AMOUNT FROM EACH END OF ROD.

THE LENGTH "L" SHALL BE THE NEAREST 25/100 AS 1825, 1850, 1875 TO FIT, FIGURING 50% TAKE UP AND 50% LET OUT. TO FIND ROD LENGTH REQUIRED SUBTRACT 1 1/4 FROM DISTANCE BETWEEN FLAT HEAD PIN CENTERS OF ASSEMBLY. THE PART NUMBER SHALL INDICATE THE LENGTH OF THE ROD.

TYPE II RODS SHALL BE DESIGNATED BY LETTER "C" AFTER BASIC NUMBER.

EXAMPLE:

AN671-3050=#6-40 ROD - 30 1/2 LONG A.C. STD.-TYPE I (CADMIUM PLATE)
AN671C3050=#6-40 ROD - 30 1/2 LONG A.C. STD.-TYPE II (COR. RES. STEEL)

MINIMUM THREAD FOR RIGID CLEVIS AND LOCK NUT - 1 1/4.

* THREADS SHALL BE IN ACCORDANCE WITH SPEC. AN-GGG-S-126

ENGINEERING INFORMATION FOR BOTH A.C. & S.A.E. STD.

R.H. RIGID CLEVIS	AN665-10R
L.H. RIGID CLEVIS	AN665-10L
CLEVIS PIN	AN393-9
PLAIN R.H. NUT	AN315-640R
PLAIN L.H. NUT	AN315-640L
MAX. ASSEMBLY LG'TH -	L + 2
MIN. ASSEMBLY LG'TH -	L + 11/16

NOTE TO AIR CORPS ACTIVITIES:
STOCK WILL BE REQUISITIONED, STORED AND ISSUED IN ACCORDANCE WITH THE LISTING GIVEN IN THE CLASSIFICATION 04A STOCK LIST.

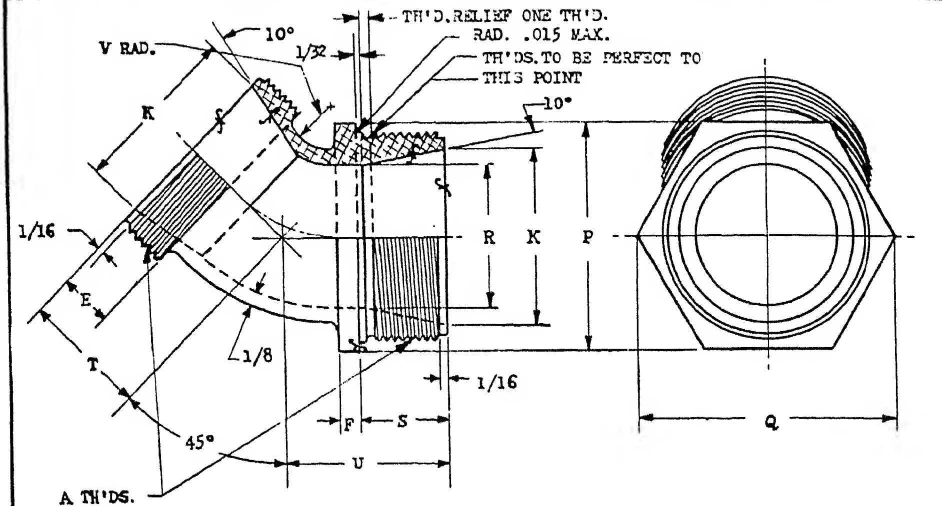
MANUFACTURING SPEC. 29-60.
LIMITS ON DIMENSIONS ± .010 UNLESS OTHERWISE SPECIFIED.
TENSILE STRENGTH - 1200#

B/M

APPROVED	AIR CORPS STOCK CLASSIFICATION - 04A	ARMY & NAVY STD.
3-22-26	TIE ROD - STREAMLINE - #6-40	AN671

REVISED 6-8-31, 4-22-35, 5-3-37, 7-1-40.

FIG. 9-17.



DASH NO.	CONDUIT SIZE	A	E	F	K	P	Q	R	S	T	U	V
3	3/16	1/2-28	3/8	1/8	.332	11/16	51/64	.167	5/8	5/8	29/32	3/16
4	1/4	5/8-24	3/8	1/8	.394	13/16	15/16	.229	5/8	21/32	15/16	3/16
6	3/8	3/4-20	3/8	1/8	.519	15/16	1 3/32	.354	5/8	11/16	31/32	3/16
8	1/2	7/8-20	3/8	3/16	.669	1 1/16	1 15/64	.479	11/16	3/4	1 1/8	1/4
10	5/8	1 -20	3/8	3/16	.794	1 1/4	1 7/16	.604	11/16	3/4	1 5/32	1/4
12	3/4	1 3/16-18	3/8	3/16	.929	1 3/8	1 19/32	.729	11/16	25/32	1 3/16	1/4
16	1	1 7/16-18	3/8	3/16	1.214	1 5/8	1 7/8	.979	11/16	31/32	1 1/4	5/16
20	1 1/4	1 3/4-18	7/16	3/16	1.469	2	2 5/16	1.229	3/4	1 1/16	1 13/32	3/8
24	1 1/2	2 -18	1/2	3/16	1.724	2 3/16	2 17/32	1.479	13/16	1 5/32	1 9/16	7/16
28	1 3/4	2 1/4-16	1/2	1/4	1.976	2 7/16	2 13/16	1.729	7/8	1 7/32	1 11/16	7/16
32	2	2 1/2-16	9/16	1/4	2.229	2 13/16	3 1/4	1.979	15/16	1 1/4	1 27/32	7/16
40	2 1/2	3 -16	5/8	1/4	2.744	3 3/8	3 57/64	2.479	1	1 3/8	2	7/16

THREADS TO BE IN ACCORDANCE WITH SPEC. AN-GGG-S-126 CLASS 3, MEDIUM FIT. NAT'L. EXTRA-FINE THREAD SERIES, SYMBOL NEF-3 FOR DASH NOS. 3 TO 24 (INCL.), NAT'L. 16-THREAD SERIES, SYMBOL 16N-3 FOR DASH NOS. 28 TO 40 (INCL.), THREADS TO BE A HAND FIT TO STANDARD GAGES.

THE FINISH SHALL BE SMOOTH MACHINE FINISH WHERE MARKED "f."

NOTE: REMOVE ALL BURRS AND SHARP EDGES.

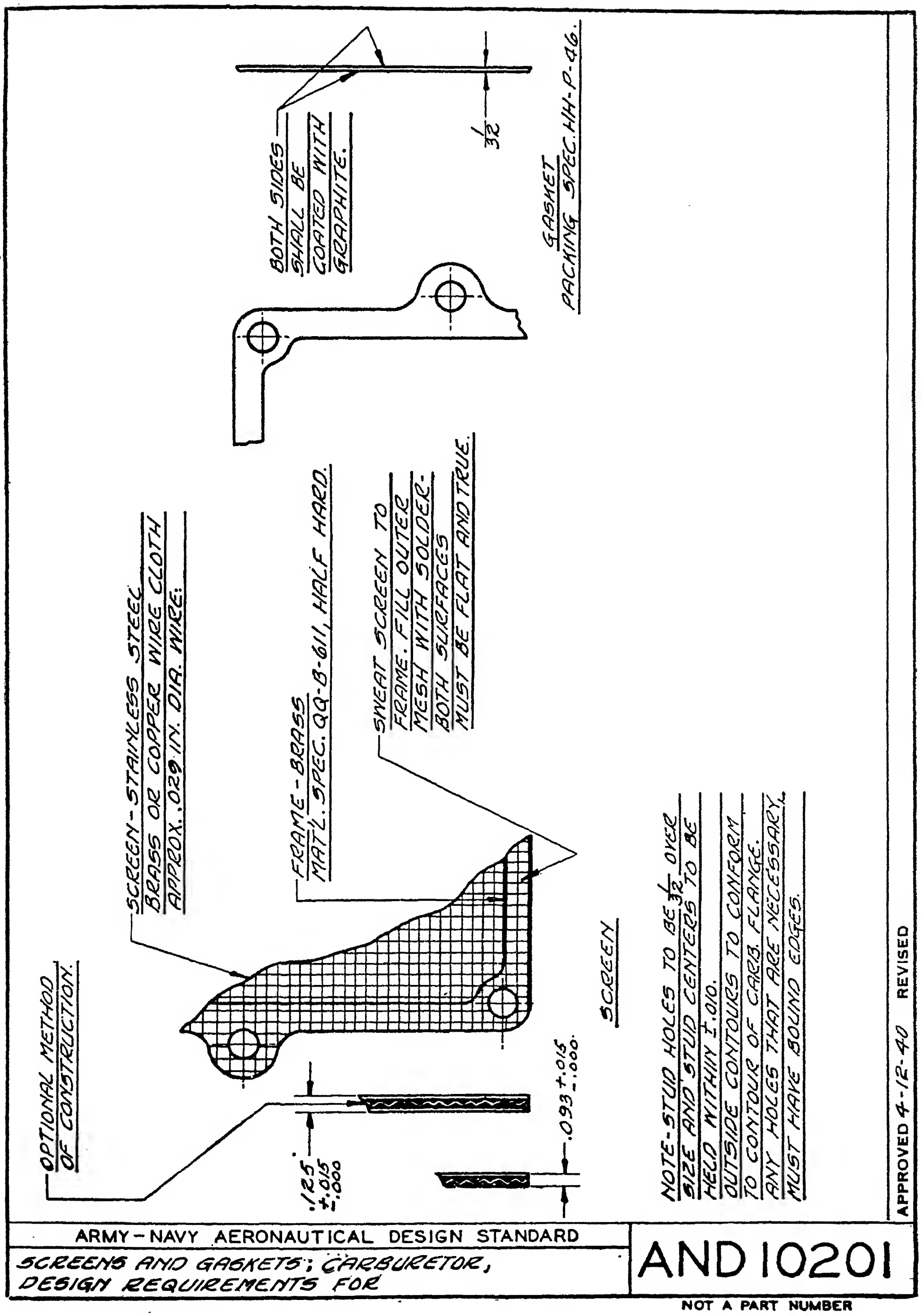
DIMENSIONS IN INCHES. LIMITS ALLOWED FOR INCHES AND FRACTIONS ±1/64, DECIMALS ±.005, ANGLES ±1/2°, UNLESS OTHERWISE SPECIFIED.

MATERIAL - ALUMINUM ALLOY - SPEC. QQ-A-601, CLASS 4, OR ALUMINUM ALLOY DIE CASTINGS OF COMMERCIAL GRADE SUITABLE TO THE PROCURING AGENCY.
FINISH - DIP IN MELTED PETROLATUM, SPEC. AN-VV-P-236, AFTER MANUFACTURE.

APPROVED 2-2-40 REVISED

PROCUREMENT SPECIFICATION	ARMY-NAVY AERONAUTICAL STANDARD	AN3060
NONE	COUPLING; CONDUIT, 45°	

FIG. 9-18.



BOTH SIDES SHALL BE COATED WITH GRAPHITE.
1/32
GASKET
PACKING SPEC. HH-P-46.
SCREEN-STAINLESS STEEL BRASS OR COPPER WIRE CLOTH APPROX. .029 IN. DIA. WIRE.
FRAME-BRASS
MAT'L. SPEC. QQ-B-611, HALF HARD.
SWEAT SCREEN TO FRAME. FILL OUTER MESH WITH SOLDER. BOTH SURFACES MUST BE FLAT AND TRUE.
OPTIONAL METHOD OF CONSTRUCTION.
.125 +.015 -.000
.093 +.015 -.000
SCREEN
NOTE-STUD HOLES TO BE 1/32 OVER SIZE AND STUD CENTERS TO BE HELD WITHIN ±.010.
OUTSIDE CONTOURS TO CONFORM TO CONTOUR OF CARB. FLANGE.
ANY HOLES THAT ARE NECESSARY MUST HAVE BOUND EDGES.
APPROVED 4-12-40 REVISED
ARMY-NAVY AERONAUTICAL DESIGN STANDARD
SCREENS AND GASKETS; CARBURETOR, DESIGN REQUIREMENTS FOR
AND 10201
NOT A PART NUMBER

FIG. 9-19.

There are many AN Standard parts for use on aircraft and aircraft equipment. These include such parts as: bearings, bolts and nuts, screws, cable fittings, keys, pins, rivets, joints and tie rods, fittings for tubes, and washers For an aircraft bolt specified as AN6D7:

AN means Army-Navy Standard
6 means diameter is 6 sixteenths of an inch
D is a code letter and means 17S aluminum alloy
7 means length is 7 eighths of an inch.

For a self locking nut AC365–624:

AC means Air Corps
365 means self locking nut
6 means for 6 sixteenths diameter bolt
24 means 24 threads per inch.

Numbers and codes are given in the Army-Navy Book Standards previously mentioned for the standard parts which have been selected for aircraft construction.

9–15. Dash Numbers. — These are numbers to identify the parts on prints which show two or more parts. Each company has its own practice in regard to the particular system developed for use on its drawings.

The principle of dash numbers is as follows: A basic drawing number is used (according to the system adopted). One system uses a prefix letter or number (as a serial number) followed by five figures such as B41079 or 241079. This is used as the number of the first left-hand part. Then B41079–1 or 241079–1 means a right-hand part which is the opposite of the left-hand part. It is called out by number but is not drawn and in this way saves time (Art. 9–8). Basic numbers with even dash numbers, –2, –4, –6, etc., are used for left-hand parts and odd dash numbers, –1, –3, –5, etc., are used for right-hand parts. The dash number as –4 or –3 is placed near to the part which it identifies and may be in the open or enclosed in a circle. A dash number identifies a part or a subassembly and so must have a name or title.

The details of numbering drawings and parts and the use of dash numbers vary somewhat in different companies and must be learned from the rules governing the system in use where the drawings are made.

CHAPTER X

FASTENINGS

10–1. Many kinds of fastenings are used in the manufacture of aircraft. Some of these are shown in this chapter. For available fastenings, materials, sizes, etc., latest United States Army and Navy Air Corps Standards (AN Standards) and company standards should be consulted at the time of selection and specification.

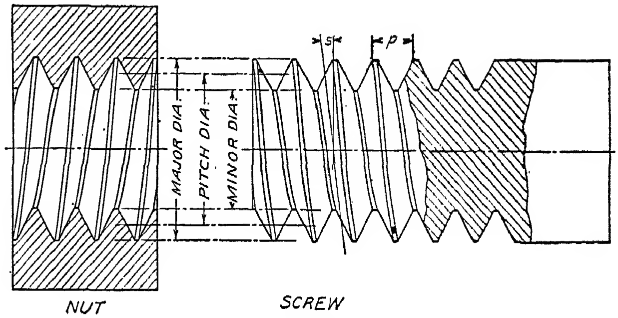


FIG. 10–1. Screw and Nut.

10–2. Screw Threads. — The American National form of thread is shown in Figs. 10–1 and 10–2 and is the thread which was previously known as the "United States Standard" or "Sellers' Profile." Full information on American Standard (National Standard) screw threads will be found in the ASA B1. 1 report of the American Standards Association, 29 W. 39th Street, New York. The report includes: form of thread, screw-thread series, terminology, screw-thread fits, and limiting dimensions and tolerances. Another source of information is the National Screw Thread Commission Report, U.S. Department of Commerce, Bureau of Standards.

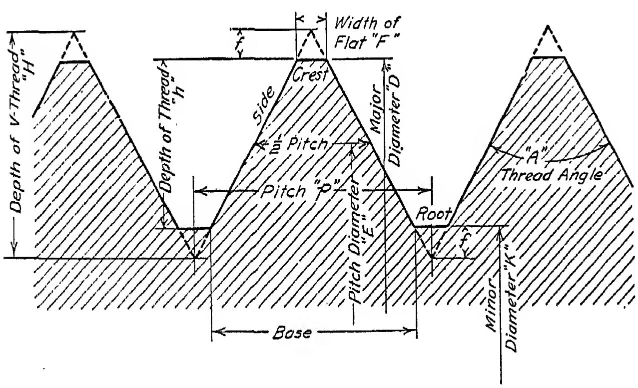


FIG. 10–2. American National Thread Profile.

The basic specifications of the thread are as follows:

Angle of thread between sides = 60 degrees.
Width of flat at crest and root = F = $\frac{1}{8} \times p$ or $0.125p$.

Depth of thread $= h = 0.649519 \times p = \dfrac{0.649519}{n}$ where p = pitch in inches. n = number of threads per inch.

Pitch $= p = \dfrac{1}{n}$. Helix angle = s.

A screw thread (Fig. 10–1) is defined as "a ridge of uniform section in the form of a helix on the external or internal surface of a cylinder."

An *external thread* is a thread on the outside of a member. An *internal thread* is a thread on the inside of a member.

The *major diameter*, the *minor diameter*, the *pitch diameter*, and other terms are illustrated on the figure. The *pitch* is "the distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis." The *lead* is the distance which the screw thread will advance axially for one turn. For single threads the pitch and lead are equal. Other parts of a screw thread are illustrated and named on Figs. 10–1 and 10–2. A *right-hand* screw thread turns in a clockwise direction to enter the nut. A *left-hand* screw thread must turn counter-clockwise to enter the nut.

10–3. Screw-Thread Series. — A number of series of screw threads have been adopted. The five American (National) screw-thread series are: the Coarse-Thread Series, the Fine-Thread Series, and three special series, the 8-Pitch-, the 12-Pitch-, and the 16 Pitch-Thread Series. Complete data is given in the ASA B1.1 report and in publications of the U.S. Department of Commerce on American National Screw Threads. The S.A.E. (Society of Automotive Engineers)

TABLE 10–1. American National and S.A.E. Standard Screw Threads
(*Coarse-thread series*, NC; *Fine-thread series*, NF; *and* S.A.E. *Extra-fine series*, EF *or* NEF)

Sizes	Major Diameter (D) (Inches)	Threads per inch (n)			Sizes	Major Diameter (D) (Inches)	Threads per inch (n)		
		NC Coarse	NF Fine	(S.A.E.) EF Extra Fine			NC Coarse	NF Fine	(S.A.E.) EF Extra Fine
0	0.0600	..	80	..	9/16	0.5625	12	18	24
1	0.0730	64	72	..	5/8	0.6250	11	18	24
2	0.0860	56	64	..	3/4	0.7500	10	16	20
3	0.0990	48	56	..	7/8	0.8750	9	14	20
4	0.1120	40	48	..	1	1.0000	8	14	20
5	0.1250	40	44	..	1 1/8	1.1250	7	12	18
6	0.1380	32	40	..	1 1/4	1.2500	7	12	18
8	0.1640	32	36	..	1 3/8	1.3750	6	12	18
10	0.1900	24	32	..	1 1/2	1.5000	6	12	18
12	0.2160	24	28	..	1 3/4	1.7500	5	..	16
1/4	0.2500	20	28	32	2	2.0000	4 1/2	..	16
5/16	0.3125	18	24	32	2 1/4	2.2500	4 1/2	..	16
3/8	0.3750	16	24	32	2 1/2	2.5000	4	..	16
7/16	0.4375	14	20	28	2 3/4	2.7500	4	..	16
1/2	0.5000	13	20	28	3	3.0000	4	..	16
					Over 3	......	....	..	16

Coarse-thread series (NC) are for general use. Fine-thread series (NF) are for special purposes requiring a fine thread. Extra-fine thread series (EF) of the Society of Automotive Engineers, Inc., (S.A.E.) are suited to "aeronautic and other applications where screw threads finer than the present fine screw-thread series are necessary."

Extra Fine Series and Special Pitch Series are given in full in the S.A.E. Handbook which should be consulted.

TABLE 10–2. American Standard Screw Threads
(8-pitch series, N8; 12-pitch series, N12; 16-pitch series, N16)

Sizes (Diameter, D, Inches)		
8 threads per inch	12 threads per inch	16 threads per inch
1″ to 2¼″ by ⅛″ increases 2½″ to 6″ by ¼″ increases	½″ to 1½″ by $\frac{1}{16}$″ increases 1⅝″ to 2¼″ by ⅛ ″ increases 2½″ to 6 ″ by ¼ ″ increases	¾″ to 4″ by $\frac{1}{16}$″ increases

8-pitch series are used on bolts and studs for high-pressure pipe flanges, cylinder heads and similar conditions where an initial tension is involved. 12-pitch series are used in certain boiler and railroad practice and for threaded collars. 16-pitch series are used on adjusting collars, retaining nuts, etc., where a fine thread is necessary.

Some thread data in condensed form are given in Tables 10–1 and 10–2.

10–4. Screw-Thread Fits. — The American (National) Standard provides four classes of screw-thread fits, briefly described in the following quotations.

Class 1 Fit. " The Class 1 fit is recommended only for screw thread work where clearance between mating parts is essential for rapid assembly and where shake or play is not objectionable."

Class 2 Fit. " Class 2 represents a high quality of commercial screw thread product and is recommended for the great bulk of interchangeable screw thread work."

Class 3 Fit. " Class 3 represents an exceptionally high grade of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking of tools is warranted."

Class 4 Fit. " Class 4 is intended to meet very unusual requirements more exacting than those for which Class 3 is intended. It is a selective fit if initial assembly by hand is required. It is not, as yet, adaptable to quantity production." . . . " These four fits are produced by the application of specific tolerances or tolerances together with allowances . . . ."

Complete tables of data should be consulted in the ASA B1.1 report described in Art. 10–2.

Class 3 Fit is the one used most for aircraft work on either the Fine-Thread Series or the Coarse-Thread Series.

10–5. Multiple Threads. — Screws may have single, double or multiple threads. For single threads the pitch and lead (Art. 10–2) are equal (Fig. 10–3 at A). When a long travel or lead is required with a small thread depth two parallel grooves are used. The result is a double thread, as at B. For a triple thread three parallel grooves are used at C. Thus, for a double thread the lead is twice the pitch and for a triple thread, three times the pitch.

10–6. Thread Symbols. — It is seldom necessary to draw the helix to represent screw threads. American Standard symbols (Figs. 10–4 and 10–5) meet the requirements of good practice. The regular symbols of Fig. 10–4 are preferred to the simplified symbols of Fig. 10–5, but both kinds are used on aircraft drawings. The pitch or actual number of threads per inch need not be to scale. The spacing

is generally assumed to look well. The cross lines may be drawn with light long lines and heavy short lines, or all the lines may be the same weight.

The methods of showing threads used by North American Aviation, Inc., are shown in Fig. 10–6.

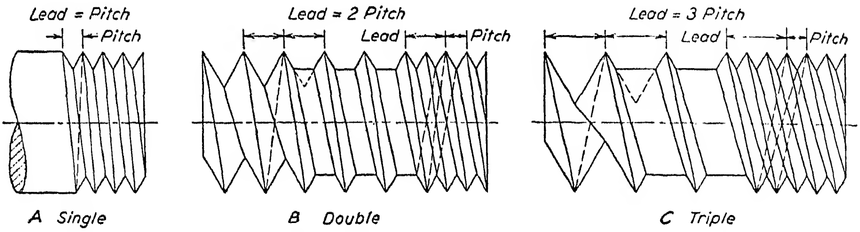


FIG. 10–3. Multiple Threads.

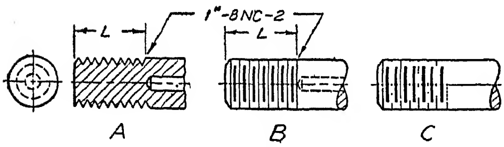


FIG. 10–4. Regular Thread Symbols. (*American Standard.*)

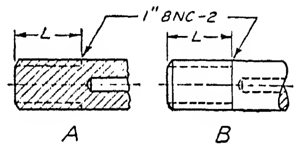


FIG. 10–5. Simplified Thread Symbols. (*American Standard.*)

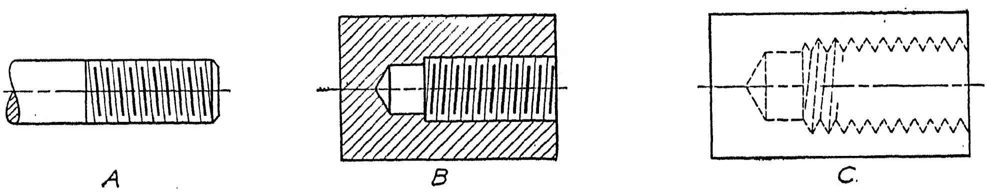


FIG. 10–6.

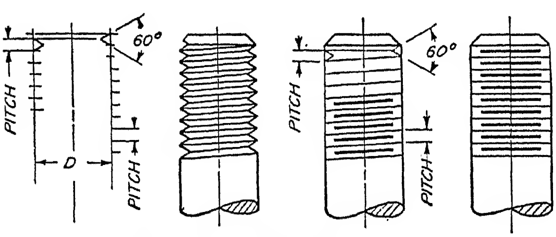


FIG. 10–7. V-Threads.

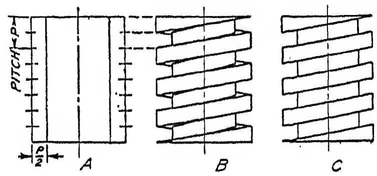


FIG. 10–8. Square Threads.

Conventional representations of V-threads and methods of drawing them are indicated in Fig. 10–7 and conventional representations of square threads in Fig. 10–8.

Internal threads are represented as in Figs. 10–9 and 10–10, threaded parts assembled, as in Fig. 10–11, and thread " pictures " as in Fig. 10–12. (Figs. 10–9 to 10–12 inclusive are from American Standards.)

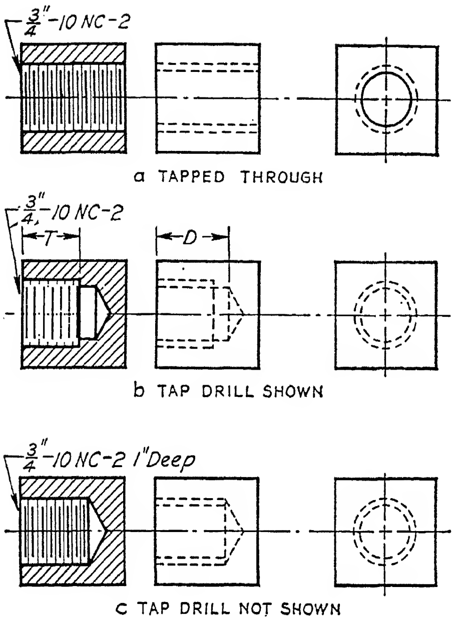


FIG. 10-9. Internal Threads. Regular Symbols.

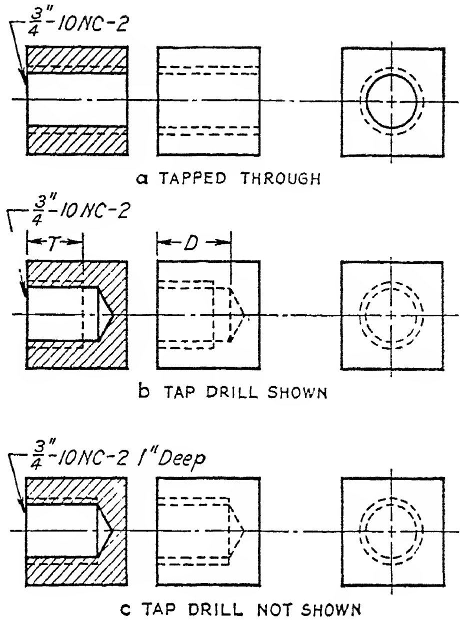


FIG. 10-10. Internal Threads Simplified Symbols.

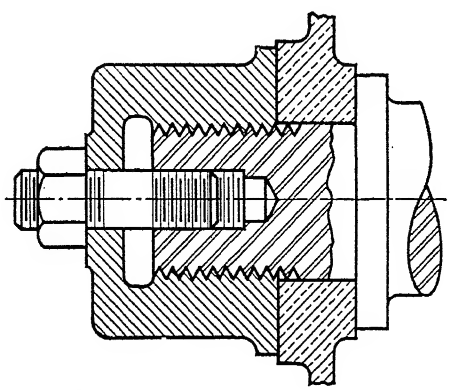


FIG. 10-11. Threads in Section. — Assembly

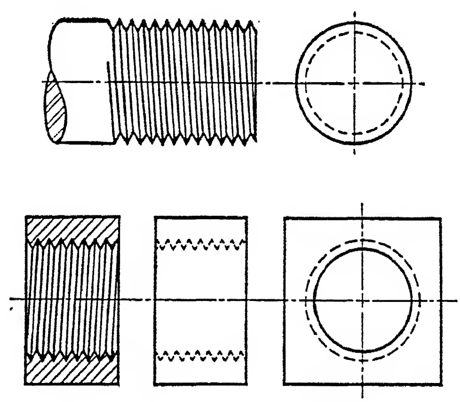


FIG. 10-12. "Thread Pictures."

10-7. Identification Symbols or Notes. — The American (National) symbols are based upon the initial letters of the series as follows:

Diameter in inches (or screw number).
Number of threads per inch.
Initials of the series: NC for coarse threads; NF for fine threads; EF for extra fine threads (S.A.E. Standard).
NS is used for National Standard form of thread with a *special* pitch.
Class of fit is given by a numeral.

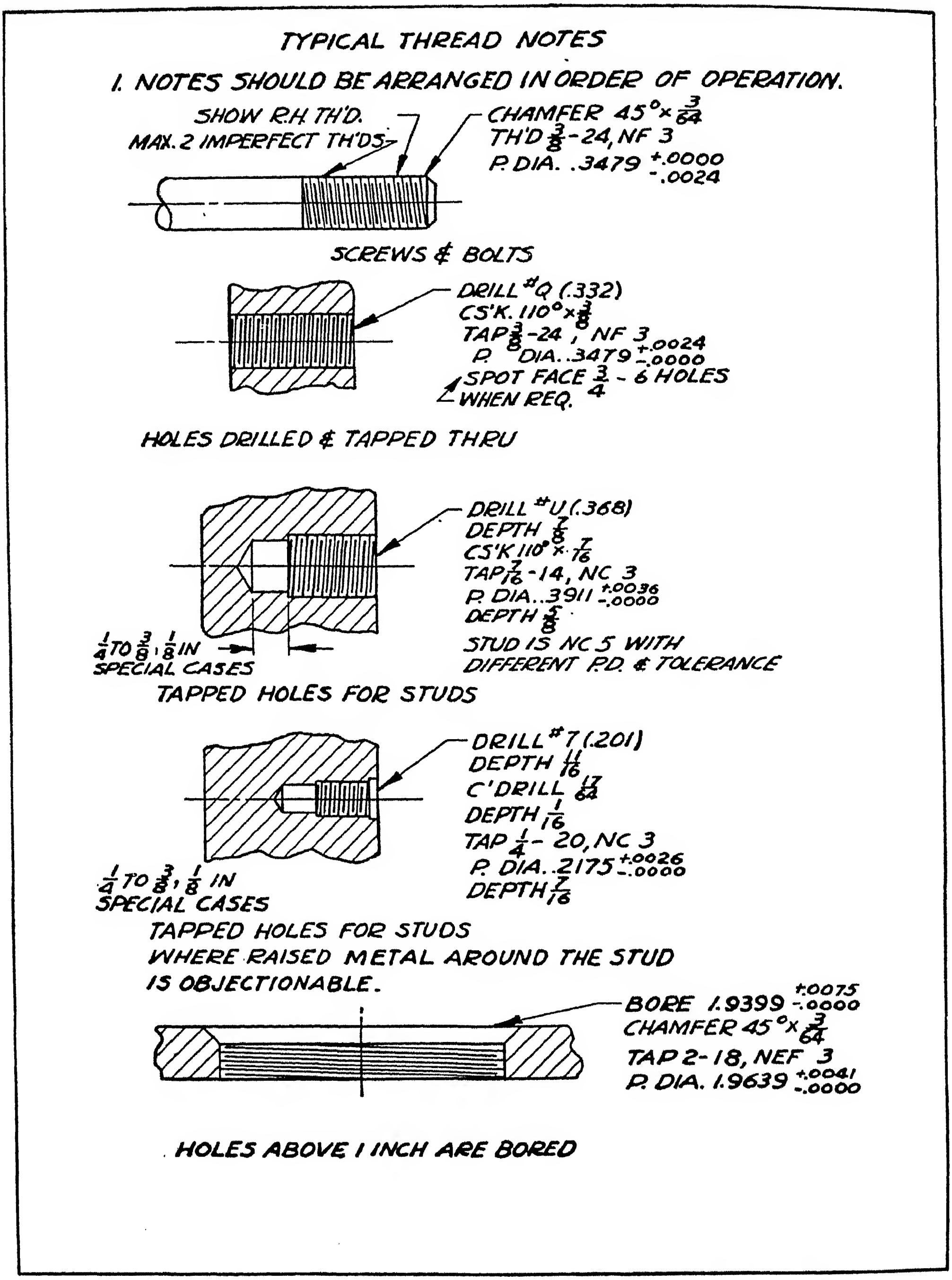


FIG. 10–13. Thread Notes. (*North American Aviation, Inc.*)

Left-hand threads use the symbol LH after the class of fit. (Aircraft practice calls for the note in full " LEFT HAND.") Threads are understood to be right hand unless otherwise noted.

Examples:

> 9/16″-12 NC-2, means 9/16″ diameter, 12 threads per inch, coarse thread series and Class 2 fit.
>
> 5/16″-24 NF-3, means 5/16″ diameter, 24 threads per inch, fine thread series and Class 3 fit. (Aircraft practice omits the inch marks.)

10–8. Thread Notes. — The uses of screw threads as to series, sizes, notes, etc., form a part of the design and drafting practice of the aircraft companies and must be followed for the company where one is employed. For example: North American Aviation, Inc., Drafting Room Manual outlines four thread series: " (1) National coarse thread, medium fit, class 3, Symbol, NC 3; (2) National fine thread, medium fit, class 3, Symbol, NF 3; (3) National extra fine thread, medium fit, class 3, Symbol, NEF 3; (4) 16 thread, medium fit, class 3, Symbol, 16N 3." (See Tables 10–1 and 10–2. NEF is same as S.A.E. Extra-fine Series.)

The manual includes tables giving all sizes in each series and explains:

..." there are certain sizes which are standard and certain sizes for restricted use."

" 1. FOR GENERAL USE:

(A) NC 3 from #1 - 64 to #8 - 32 inclusive
(B) NF 3 from #10 - 32 to 1 - 14 inclusive
(C) NEF 3 from 1 1/16 - 18 to 2 - 18 inclusive, except 1 9/16, 1 11/16, 1 13/16 and 1 15/16.
(D) 16N 3 from 2 1/16 and up."

" 2. FOR SPECIAL USES:

(A) NC 3 from #10 - 24 and up for studs in castings
(B) NEF 3 in all sizes where an extra fine thread is needed. Example: A thin walled section.
(C) All sizes of each series may be used where it is necessary to match commercial parts."

Aircraft drawings often indicate the order of operations in the thread specification notes as shown in Figs. 10–13, 10–14 and 10–15 which indicate the practice of North American Aviation, Inc., and the Lockheed Aircraft Corporation. The symbol NEF means National Extra Fine thread and the symbol NS means National form of thread with special pitch.

10–9. Acme Thread. — This is a modification of the square thread and is illustrated in Fig. 10–16. The number of threads per inch is selected to meet the requirements of the design and is not related to the given diameter. Company standards should be consulted and complete data for manufacture given on the drawings.

10–10. Aircraft Bolts and Nuts. — An aircraft bolt is shown in Fig. 10–17, and some dimensions are given in Table 10–3. These bolts have hexagon heads and washer-face bearing surfaces. The same shapes and dimensions apply to either steel or aluminum alloy bolts, but with a distinctive marking on the head as illustrated: *A*. Alum. Alloy — Plain, unmarked; *B*. Alum. Alloy — AN specifications; *C*. Alloy steel. American (National) Standard Fine threads

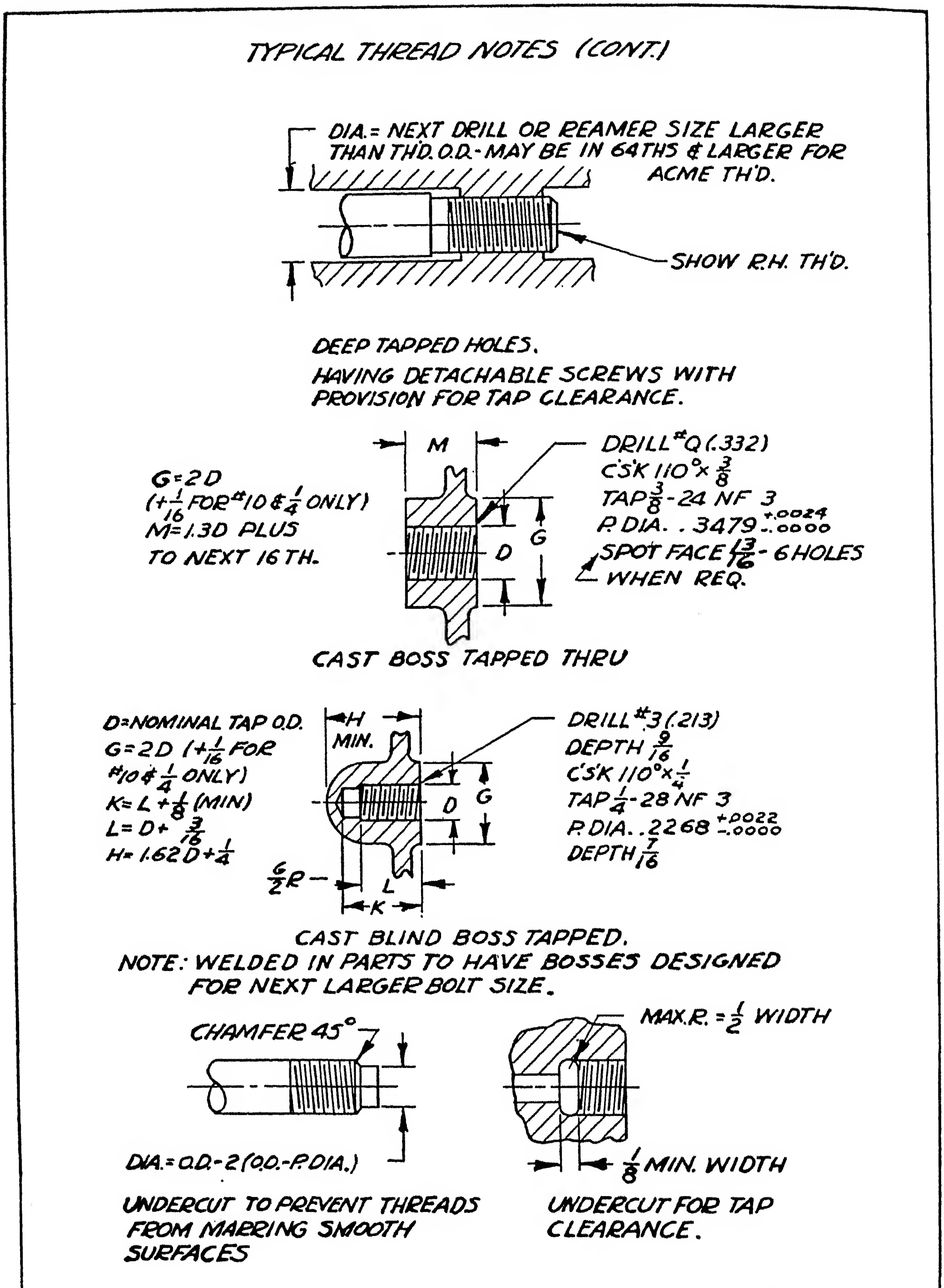


Fig. 10-14. Thread Notes. (*North American Aviation, Inc.*)

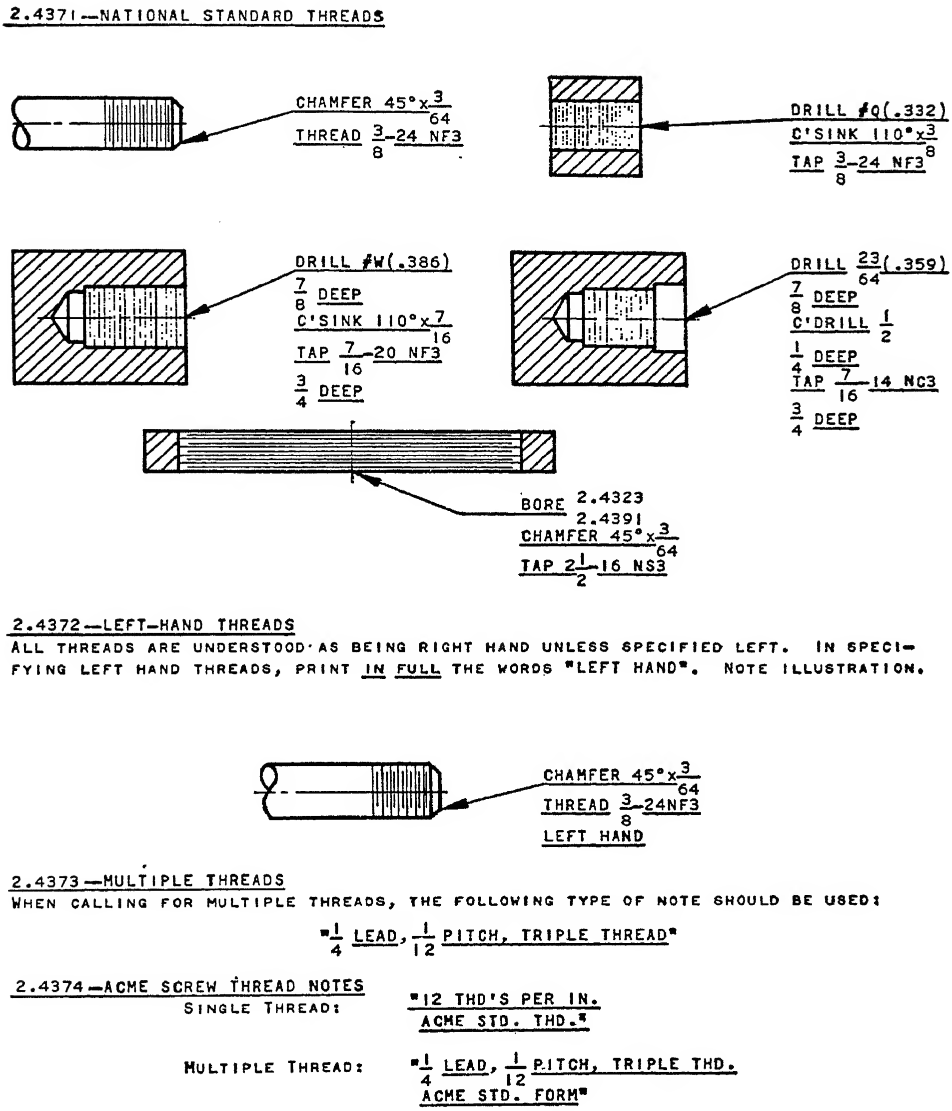


Fig. 10–15. Thread Notes. (*Lockheed Aircraft Corporation.*)

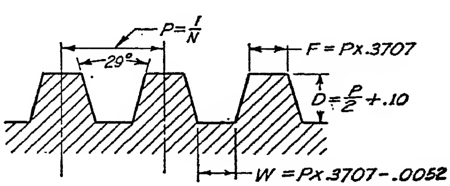


Fig. 10–16. 29° Acme Thread.

TABLE 10-3. AIRCRAFT BOLTS (Fig. 10-17)

Size D	Thds. per Inch	A	B	C	E	T	Cotter Pin AN380	Drill for Cotter H
No. 10 .189	32	1/8	.375	7/16	1/4	3/8	-2-2	.070
1/4	28	5/32	.4375	1/2	9/32	7/16	-2-2	.076
5/16	24	3/16	.500	37/64	21/64	7/16	-2-2	.076
3/8	24	7/32	.5625	21/32	13/32	9/16	-3-3	.106
7/16	20	1/4	.625	23/32	29/64	9/16	-3-3	.106
1/2	20	9/32	.750	7/8	9/16	11/16	-3-3	.106
9/16	18	5/16	.875	1 1/64	39/64	3/4	-4-4	.141
5/8	18	11/32	.9375	1 3/32	11/16	13/16	-4-4	.141
3/4	16	13/32	1.0625	1 15/64	13/16	15/16	-4-5	.141
7/8	14	15/32	1.250	1 7/16	29/32	1 1/16	-4-5	.141
1	14	17/32	1.4375	1 21/32	1	1 1/8	-4-6	.141

(NF) with Class 3 Fit are used. (Class 2 Fit is necessary when certain purchased parts are used.) Bolt lengths increase by 1/8 in. from 3/8 to 8 in. Dash numbers increase by eighths, even inches by multiples of 10, thus: 2 5/8 in. long = −25. To specify an undrilled bolt add "A" to the Part No., thus: AN4–4A. To specify a drilled head add "D.H." to the Part No., thus: AN4–4A(D.H.).

A stud bolt or stud is a cylindrical rod having threads on both ends, Fig. 10–18.

10–11. Some of the most used aircraft nuts are illustrated in Fig. 10–19, and dimensions and other data are given in Tables 10–4 and 10–5.

TABLE 10-4. AIRCRAFT NUTS (Fig. 10-10)

Size of Bolt	Thds. per Inch	A	B	C	E	F	G	H	J	K
No. 10	32	9/64	3/8 + .002	7/16	15/64	5/64	1/4	9/64	5/64	3/16
1/4	28	3/16	7/16 + .002	1/2	5/16	5/64	9/32	5/32	5/64	3/16
5/16	24	15/64	1/2 + .002	37/64	11/32	3/32	21/64	5/32	5/64	3/16
3/8	24	9/32	9/16 + .0025	21/32	29/64	3/32	13/32	3/16	1/8	7/32
7/16	20	21/64	5/8 + .0025	23/32	29/64	7/64	29/64	3/16	1/8	7/32
1/2	20	3/8	3/4 + .0025	7/8	19/32	7/64	9/16	13/64	1/8	1/4
9/16	18	27/64	7/8 + .0025	1 1/64	11/16	5/32	39/64	7/32	5/32	5/16
5/8	18	15/32	1 + .0025	1 5/32	3/4	11/64	11/16	7/32	5/32	5/16
3/4	16	9/16	1 1/8 + .003	1 19/64	7/8	3/16	13/16	1/4	5/32	3/8
7/8	14	21/32	1 5/16 + .003	1 33/64	1	7/32	29/32	1/4	5/32	7/16
1	14	3/4	1 1/2 + .003	1 47/64	1 1/8	7/32	1	1/4	5/32	1/2

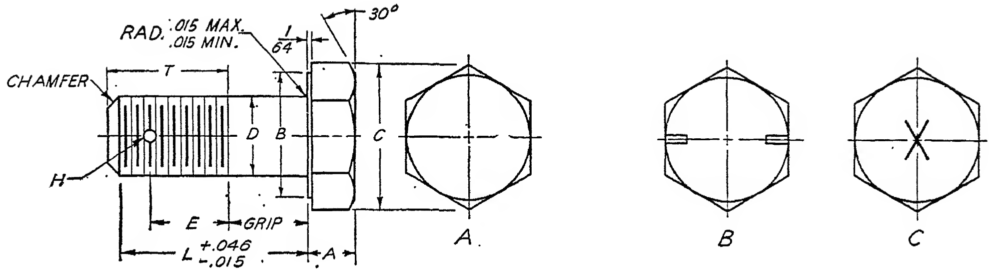


FIG. 10–17. Aircraft Bolt.

TABLE 10–5. BOLTS AND NUTS (Dash Numbers)

Size of Bolt	Thds. per Inch	Bolt	Bolt Diameter	Self Lock Nut AC365	Castle Nut AN310	Plain Nut AN315	Shear Nut AN320
No. 10	32	AN3	.189 $^{+.0000}_{-.0025}$	–1032	–3	–3R	–3
¼	28	AN4	.249 $^{+.000}_{-.003}$	–428	–4	–4R	–4
5/16	24	AN5	.3115 $^{+.000}_{-.003}$	–524	–5	–5R	–5
⅜	24	AN6	.374 $^{+.000}_{-.003}$	–624	–6	–6R	–6
7/16	20	AN7	.4365 $^{+.0000}_{-.0035}$	–720	–7	–7R	–7
½	20	AN8	.499 $^{+.0000}_{-.0035}$	–820	–8	–8R	–8
9/16	18	AN9	.5615 $^{+.000}_{-.004}$		–9	–9R	–9
⅝	18	AN10	.624 $^{+.000}_{-.004}$		–10	–10R	–10
¾	16	AN12	.749 $^{+.0000}_{-.0045}$		–12	–12R	–12
⅞	14	AN14	.874 $^{+.000}_{-.005}$		–14	14R	–14
1	14	AN16	.999 $^{+.0000}_{-.0055}$		–16	–16R	–16

1. Add "A" to the part number to specify undrilled bolt, i.e. AN4–4A.
2. Add D.H. to the part number to specify drilled head, i.e, AN4–4A (D.H.).

Elastic stop nuts are made in many different types some of which are illustrated in Fig. 10–20. This patented elastic stop nut is described as a standard

TABLE 10–6. ELASTIC STOP NUTS (Fig. 10–20)

Catalog Number	U.S. Army Air Corps Stds. No.	Size	Thds. per Inch	Dia. Hex.	H	E	Catalog Number	Size	Thds. per Inch	Dia. Hex.	H	E
42E048	365–428	1/4	28	7/16	5/16	5/64	42E098	9/16	18	7/8	11/16	5/32
42E054	365–524	5/16	24	1/2	11/32	3/32	42E108	5/8	18	15/16	3/4	11/64
42E064	365–624	3/8	24	9/16	29/64	3/32	42E126	3/4	16	1 1/16	7/8	3/16
42E070	365–720	7/16	20	5/8	29/64	7/64	42E144	7/8	14	1 1/4	1	7/32
42E080	365–820	1/2	20	3/4	19/32	7/64	42E164	1	14	1 7/16	1 1/8	7/32

X 315 Steel, cadmium plated.
(American National Fine Thread Series)
(Class 3 Thread Fit)

TABLE 10–7. ELASTIC STOP NUTS, TWO LUG ANCHOR (Fig. 10–20)
Type A1 amd Type A2

Size	A	B	C	D	E	F
No. 6	31/32	25/64	11/32	25/64	13/64	9/32
No. 8	31/32	25/64	11/32	7/16	1/4	11/32
No. 10	31/32	25/64	11/32	7/16	1/4	11/32
1/4	1 9/32	1/2	1/2	....	9/32	....

For dash numbers, sizes available in steel and aluminum and finishes, see AC Standards and Elastic Stop Nut Corporation Catalog.

TABLE 10–8. MAXIMUM DIMENSIONS FOR MACHINE SCREW HEADS (Fig. 10–22)

Nominal Size	D	A	B	C	E	F	G	H	J	M	N	O	P	T
2	.086	.172	.162	.070	.048	.029	.023	.051	.036	.140	.055	.028	.037	.045
3	.099	.199	.187	.078	.053	.033	.027	.059	.038	.161	.063	.032	.043	.052
4	.112	.225	.211	.086	.058	.037	.030	.067	.040	.183	.072	.035	.048	.059
5	.125	.252	.236	.095	.062	.041	.034	.075	.043	.205	.081	.039	.054	.067
6	.138	.279	.260	.103	.067	.045	.038	.083	.045	.226	.089	.043	.060	.074
8	.164	.332	.309	.119	.076	.053	.045	.100	.050	.270	.106	.050	.071	.088
10	.190	.385	.359	.136	.086	.061	.053	.116	.055	.313	.123	.057	.083	.103
12	.216	.438	.408	.152	.095	.069	.060	.132	.059	.357	.141	.064	.094	.117
1/4	.250	.507	.472	.174	.108	.079	.070	.153	.066	.414	.163	.074	.109	.136
5/16	.3125	.636	.591	.214	.130	.098	.088	.192	.077	.519	.205	.092	.137	.171
3/8	.375	.762	.708	.254	.153	.117	.106	.230	.088	.622	.246	.109	.164	.206

For threads per inch see Tables 10–1 and 10–2. Coarse Thread and Fine Thread Series. Class 3 Fit. Screws 1 1/4 and under in length are threaded to head — over 1 1/4 are threaded not less than 1 1/4.

nut with the height increased to incorporate a fiber collar (added height approximates the thickness of a lock washer). The hole in the fiber collar is smaller

than the bolt. The bolt threads do not cut a thread but impress themselves into the fiber. Some dimensions are given for Elastic Stop Aircraft Nuts in Tables 10–6 and 10–7.

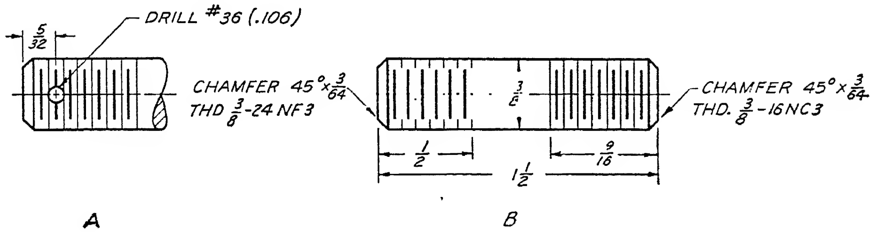


Fig. 10–18. A Stud.

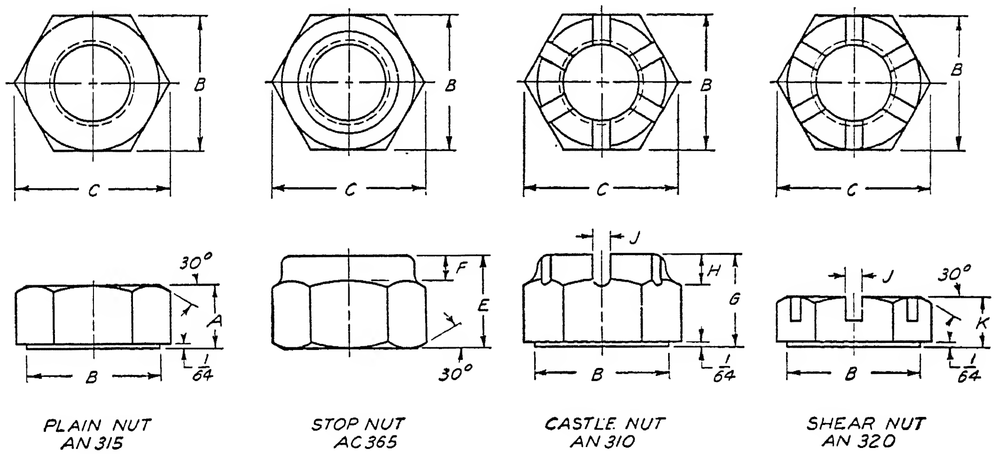


Fig. 10–19. Aircraft Nuts.

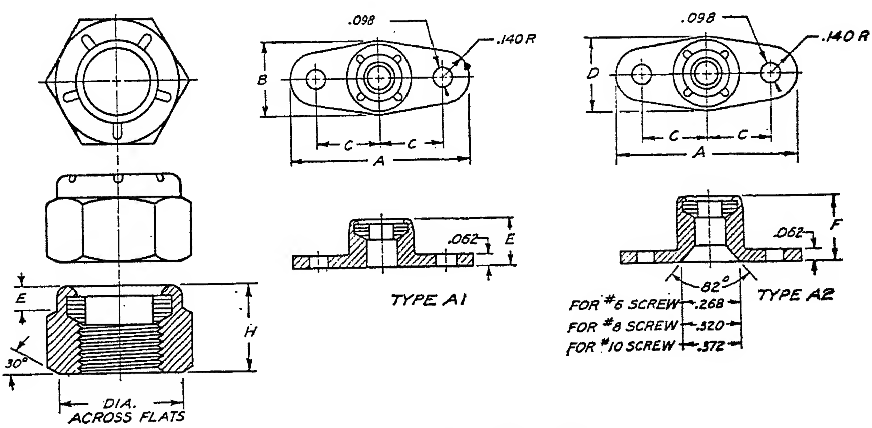


Fig. 10–20. Elastic Stop Nuts.

10-12. To Draw an Aircraft Bolt Head or Nut, (Fig. 10-21). — Obtain dimensions from Tables 10-3 and 10-4 and refer to Figs. 3-24 and 3-27 for drawing a hexagon. Draw the center line or axis and a line to represent the contact surface of the bolt head (Fig. 10-21) and the diameter. Lay off one-half the width across flats or one-half the distance across corners (whichever is required) on

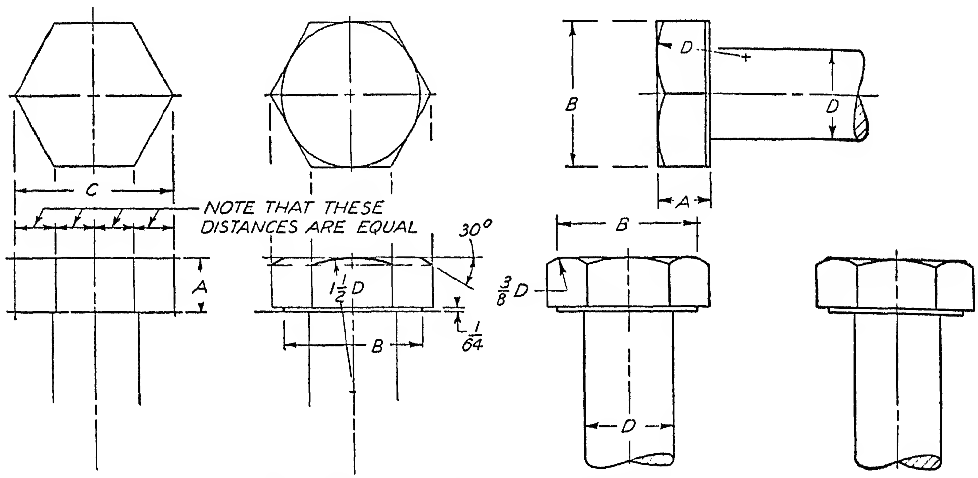


Fig. 10-21. To Detail an Aircraft Bolt Head:

each side of the center line. Lay off the height of the bolt head. Then draw the necessary lines to block in the view. Draw arcs with radii as indicated.

The construction for drawing any of the aircraft nuts is the same as described for a bolt head, using the proper dimensions for the required nut.

10-13. Machine screws (Figs. 10-22 and 10-23) are adapted for use with small parts of aircraft. They are especially made for this purpose to conform with the applicable specifications of cadmium plated steel, brass, and aluminum

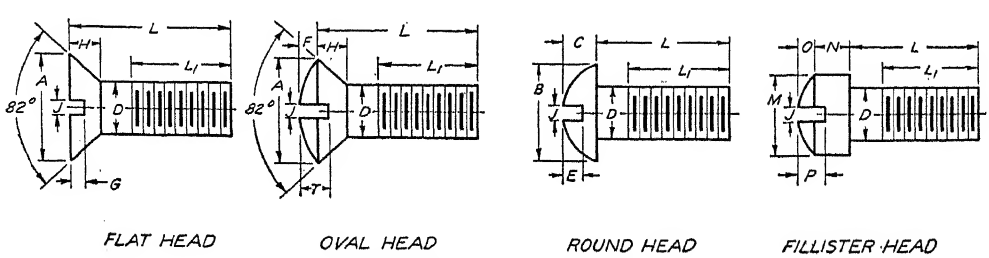
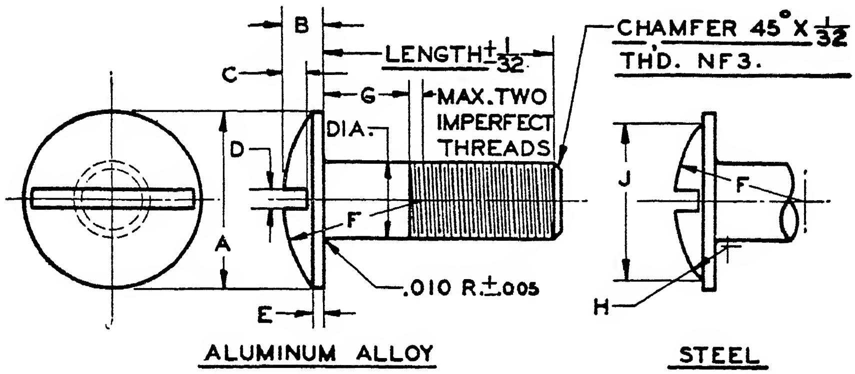


Fig. 10-22. Machine Screws.

alloy. Coarse or fine thread series may be used. For lengths of 1¼″ or less they are threaded full length. Longer screws are threaded not less than 1¼″. Table 10-8 gives suitable dimensions for drawing machine screws. For dash numbers applying to various sizes, materials, finishes, etc., the AN Standards should be consulted.



SIZE	DIA. +.0000 -.0025	A	B ±.005	C ±.005	D	E +.005 .000	F	PITCH DIA.	H	J
#8-36	.164	.375	.087	.049	.043	.023	.312	.1460 +.0000 -.0018	.078	.312
#10-32	.190	.437	.094	.054	.047	.025	.398	.1697 +.0000 -.0019	.078	.375
1/4-28	.250	.500	.101	.058	.053	.028	.474	.2268 +.0000 -.0022	.097	.437

LENGTH	G	DASH NUMBERS #8	#10	1/4
3/8	1/32	8-6	10-6	416-6
7/16	1/16	8-7	10-7	416-7
1/2	1/8	8-8	10-8	416-8
9/16	5/32	8-9	10-9	416-9
5/8	7/32	8-10	10-10	416-10
11/16	9/32	8-11	10-11	416-11
3/4	11/32	8-12	10-12	416-12
7/8	15/32	8-14	10-14	416-14
1	19/32	8-16	10-16	416-16

LENGTH	G	DASH NUMBERS #8	#10	1/4
1 1/8	23/32	8-18	10-18	416-18
1 1/4	27/32	8-20	10-20	416-20
1 3/8	31/32	8-22	10-22	416-22
1 1/2	1 3/32	8-24	10-24	416-24
1 5/8	1 7/32	8-26	10-26	416-26
1 3/4	1 11/32	8-28	10-28	416-28
1 7/8	1 15/32	8-30	10-30	416-30
2	1 19/32	8-32	10-32	416-32

EXAMPLE OF PART NUMBER: 525-8-7 FOR NICKEL STEEL SCREW
525D8-7 FOR ALUMINUM ALLOY SCREW

NOTE: BEARING SURFACE OF HEAD MUST BE FREE FROM BURRS AND TOOL MARKS.

MATERIAL - STEEL - SPEC. 57-107-17
ALUM. ALLOY - SPEC. QQ-A-354

*THREADS SHALL BE IN ACCORDANCE WITH SPEC. AN-GGG-S-126.
TENSILE STRENGTH - STEEL 125000# PER SQ. IN. MIN.
ALUM. ALLOY 62000# PER SQ. IN. MIN.

FINISH - STEEL, SPEC. 57-107-17 CADMIUM PLATE SPEC. AN-QQ-P-421
ALUMINUM ALLOY - ANODIC TREATMENT SPEC. 98-20005

PACKING SPEC. 40560
LIMITS ON DIMENSIONS ±.010 UNLESS OTHERWISE SPECIFIED.

APPROVED	AIR CORPS STOCK CLASSIFICATION 29	
9-25-35	SCREW - WASHER HEAD	525

FIG. 10–23. Washer Head Screws.

Washer-head screws are illustrated in Fig. 10–23 which also gives dimensions and dash numbers. Dimensions of machine screw nuts are given in Table 10–9.

10–14. Miscellaneous screws, nuts, etc., are illustrated and named in Fig. 10–24. For data on sizes, materials, etc., AN Standards and manufacturers' descriptive data should be consulted.

Dimensions of aircraft flat washers, regular series, are given in Table 10–10.

TABLE 10–9. MACHINE SCREW NUTS

Nominal Size	2	3	4	5	6	8	10	12	1/4
Distance Across Flats	3/16	3/16	1/4	5/16	5/16	11/32	3/8	7/16	7/16
Thickness	1/16	1/16	3/32	7/64	7/64	1/8	1/8	5/32	5/32

Washer face 1/64 thick. AN340, Coarse Thread. AN345, Fine Thread.

TABLE 10–10. AIRCRAFT PLAIN WASHERS

Size	#3	#4	#6	#8	#10	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1
Inside Dia.	7/64	1/8	9/64	11/64	13/64	17/64	21/64	25/64	29/64	33/64	37/64	41/64	49/64	57/64	1 1/64
Outside Dia.	1/4	5/16	3/8	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1 1/16	1 3/16	1 5/16	1 1/2	1 3/4
Thickness	1/32	1/32	1/32	1/32	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	3/32	3/32	3/32

AN, 960. Carbon steel. Regular series.

TABLE 10–11. ALUMINUM AND ALUMINUM ALLOY AIRCRAFT RIVETS (Fig. 10–30)

Dash No.	Dia. D	A	B	C	E	F	G
–2	1/16	.117	1/8	5/32	1/32	.047	.025
–3	3/32	.168	3/16	15/64	3/64	.070	.038
–4	1/8	.226	1/4	5/16	1/16	.094	.050
–5	5/32	.282	5/16	25/64	5/64	.117	.062
–6	3/16	.339	3/8	15/32	3/32	.141	.075
–8	1/4	.452	1/2	5/8	1/8	.188	.100
–10	5/16	.565	5/8	25/32	5/32	.234	.125
–12	3/8	.678	3/4	15/16	3/16	.281	.150

Dimensions nominal.

10–15. Pipe Threads. — American (National) pipe threads are shown in Fig. 10–25. Conventional representations as indicated in Fig. 10–26 may be drawn as at *A* or *B* or the taper shown as at *C*. Dimensions of American Standard Pipe are given in Figs. 10–27 and 10–28 for nominal sizes from 1/8 to 2.

10–16. Aluminum aircraft rivets are made with four shapes of heads and of aluminum and aluminum alloys. Standard head markings are used for alloy identification as indicated in Fig. 10–29. Some dimensions for the different shapes of heads (Fig. 10–30) are given in Table 10–11.

Type A is made of 2S aluminum and requires no heat treatment before using.

Type D is made of 17ST aluminum alloy and must be heat-treated before using. Min. shear, 30,000#/sq. in.

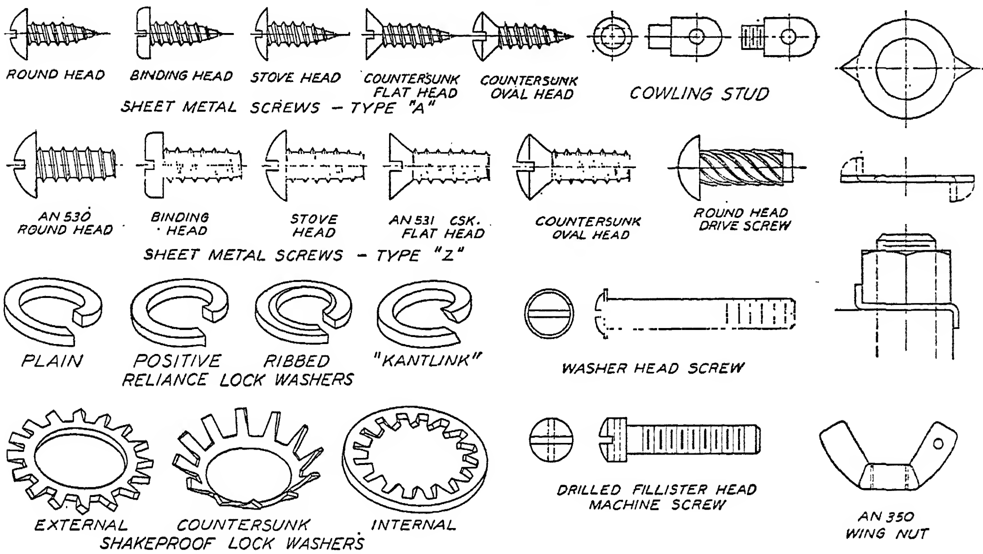


Fig. 10–24. Miscellaneous Screws, Nuts, Etc.

Type AD is made of A17S-T aluminum alloy and must NOT be heat-treated before using. Min. shear, 25,000#/sq. in.

Type DD is made of 24S-T aluminum alloy and must be heated before using. Min. shear, 35,000#/sq. in.

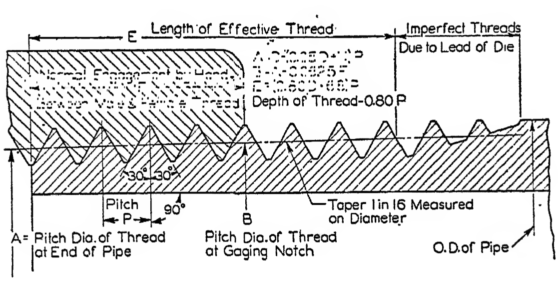


Fig. 10–25. American National Standard Pipe Thread.

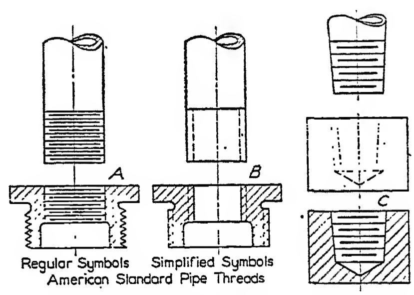
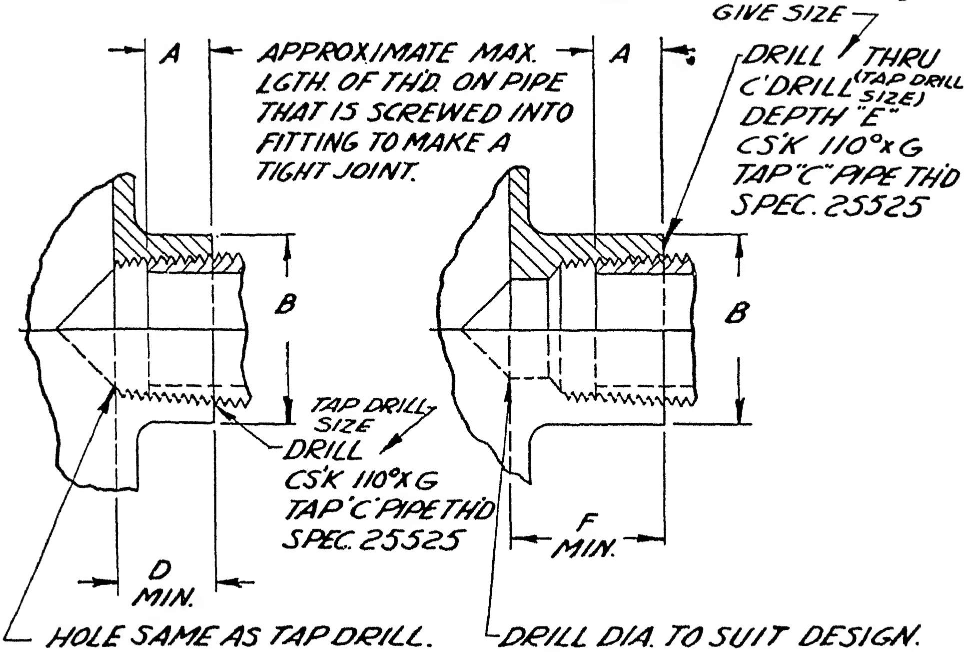


Fig. 10–26. Pipe Thread Symbols.

Code: AN425–4–6 means type A with countersunk head, $\frac{1}{8}''$ diameter and $\frac{3}{8}''$ long (the first dash number is the number of 32nds diameter ($\frac{4}{32}$ dia.) and the last number is the length in 16ths ($\frac{6}{16}$ long)). In like manner: AN430D–8 means round head, $\frac{3}{32}$ inch diam., $\frac{1}{2}$ inch long; AN442AD4–10 means flat head

DIMENSIONS OF INTERNAL TAPER PIPE THREADS
NATIONAL (AMERICAN BRIGGS) TAPER PIPE THREAD STANDARD



REDUCE THIS DIM. 25% FOR FRAGILE FITTINGS.

C PIPE SIZE	A	B	D	E	F	G	THD PITCH	TAP DRILL
1/8	19/64	11/16	7/16	7/16	9/16	13/32	.037	"R" .339
1/4	23/64	27/32	19/32	19/32	3/4	9/16	.055	7/16
3/8	13/32	1	5/8	5/8	13/16	11/16	.055	37/64
1/2	17/32	1 7/32	13/16	13/16	1 1/32	7/8	.071	23/32
3/4	35/64	1 15/32	27/32	27/32	1 1/16	1 1/16	.071	59/64
1	21/32	1 3/4	1	1	1 9/32	1 5/16	.087	1 5/32
1 1/4	11/16	2 1/8	1 1/32	1 1/32	1 9/32	1 43/64	.087	1 1/2
1 1/2	11/16	2 13/32	1 1/32	1 1/32	1 9/32	1 29/32	.087	1 47/64
2	11/16	2 7/8	1 1/16	1 1/16	1 5/16	2 3/8	.087	2 7/32

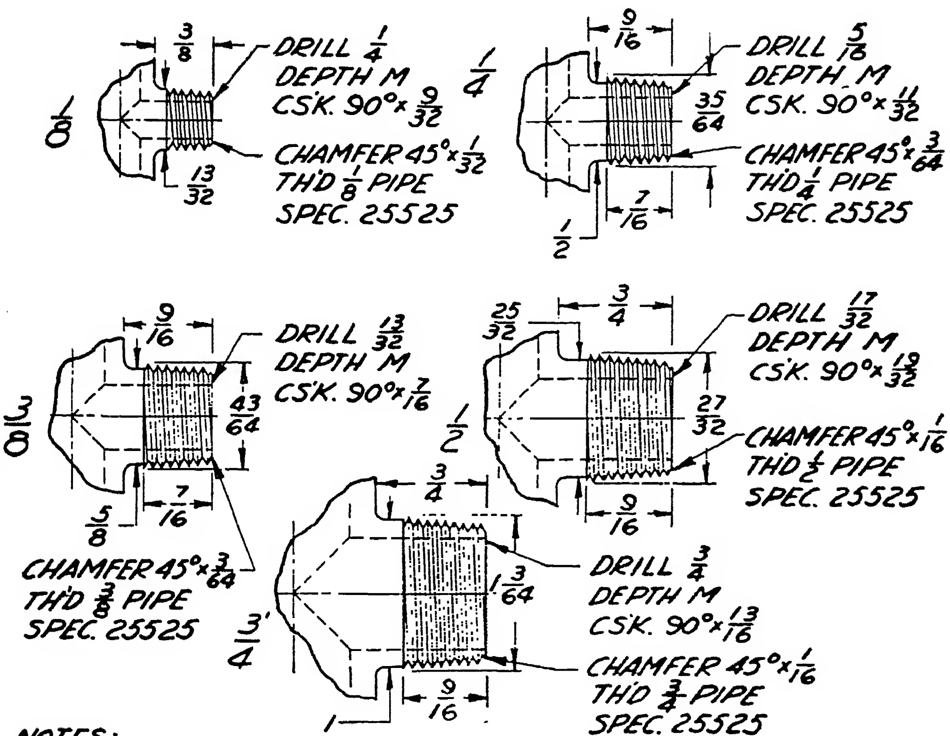
D = HUB HEIGHT = A + 4 THDS APPROX.
A = APPROX. L_3 AS GIVEN IN SPEC. 25525.

NOTES:
1. ALL BOSSES IN STEEL TO BE $\frac{1}{8}$ SMALLER THAN "B."
2. "F" & "E" MAY ALSO BE INCREASED TO AVOID THE NECESSITY OF GRINDING OFF "LEAD" OF TAP TO THREAD SHORT HOLE.
3. IN POWER PLANT & OTHER IMPORTANT WORK PROVIDE FOR NEXT LARGER TAP.

FIG. 10-27. Internal Taper Pipe Threads. (*North American Aviation, Inc.*)

DIMENSIONS OF EXTERNAL PIPE THREADS
NATIONAL (AMERICAN BRIGGS) TAPER PIPE THREAD STANDARD

ALL PIPE THREADS SHOWN ARE FOR NATIONAL STANDARD TAPER.



NOTES:
DEPTH "M" TO SUIT DESIGN.
THE LENGTHS OF THE THREADED BOSSES AS SHOWN ARE MIN. & SHOULD BE USED UNLESS OTHER FACTORS OF THE DESIGN DICTATE THE USE OF GREATER LENGTHS. THE DIMENSIONS OF THE BOSSES SHOWN BETWEEN THE BODY & THE END OF THE THREAD ARE MIN & SHOULD BE USED WHERE THIS PORTION IS REDUCED OVER THE OUTSIDE DIA. OF THE THREAD. THE LENGTH OF THE THREAD AS SHOWN SHALL BE SPECIFIED ONLY WHEN THE PORTION BETWEEN THE BODY & THE END OF THE THREAD IS REDUCED MAKING IT NECESSARY FOR PATTERN OR DIE MAKER TO MAKE ALLOWANCE FOR THE THREAD. IT SHALL NOT BE SPECIFIED IN CASES AS INDICATED ON THE 1/8 PIPE THREAD WHERE THE OUTSIDE DIAMETER OF THE PORTION BEYOND THE THREAD IS LARGER THAN THE OUTSIDE DIA. OF THE PIPE THD.

FIG. 10-28. External Taper Pipe Threads. (*North American Aviation, Inc.*)

1/8 inch diam., 5/8 inch long; AN442DD6–12 means brazier head, 3/16 inch dia., 3/4 inch long.

10–17. Pins of many types are used for fastenings on aircraft. Some kinds are illustrated in Figs. 10–31, 10–32 and 10–33, and some dimensions are given in Tables 10–12 and 10–13.

TABLE 10–12. CLEVIS PIN (Fig. 10–31)

Nom. Dia.	Dimensions					Drill "F"	
	A	B	C	D	E	No.	Size
1/8	1/4	3/64	3/64	.124	G + .035	50	.070
5/32	9/32	3/64	3/64	.155	G + .035	50	.070
3/16	5/16	3/64	3/64	.186	G + .038	48	.076
1/4	3/8	1/16	1/16	.248	G + .038	48	.076
5/16	7/16	1/16	5/64	.311	G + .053	36	.1065
3/8	1/2	1/16	5/64	.373	G + .053	36	.1065
7/16	9/16	3/32	5/64	.436	G + .053	36	.1065
1/2	5/8	3/32	5/64	.497	G + .053	36	.1065

TABLE 10–13. PLAIN TAPER PIN (Fig. 10–32)

Dia. "D" Large End	Length		Dia. "D" Large End	Length	
	Min.	Max.		Min.	Max.
.078	1/2	1/2	.172	3/4	2
.094	1/2	3/4	.193	3/4	2 1/2
.109	1/2	3/4	.219	1	2 3/4
.125	3/4	1	.250	1 1/2	3
.141	3/4	1 1/2	.289	1 3/4	3
.156	3/4	1 3/4	.341	2	3

For plain taper pin. To determine diameter of the small end, multiply the length by .021 and subtract the result from the diameter at the large end.

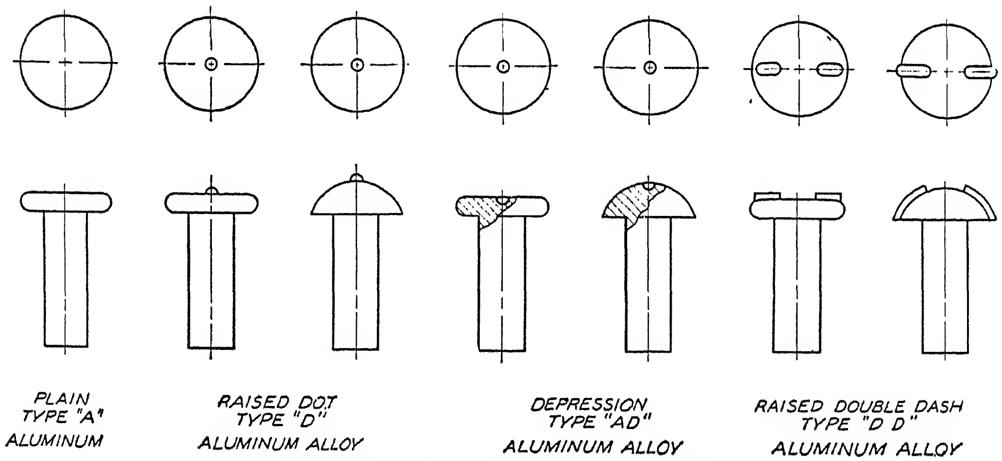


FIG. 10–29. Alloy Identification for Rivets.

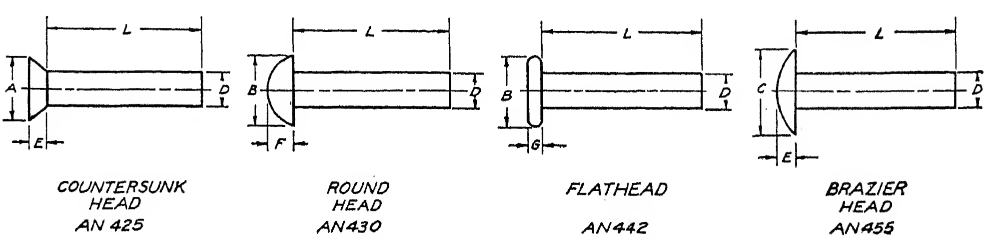


FIG. 10–30. Rivet Heads.

10–18. Woodruff keys consist of a portion of a circular disc, Fig. 10–34. The circular seating allows the key to adjust itself to the proper taper when a piece is keyed to a shaft. Dimensions are given in Table 10–14.

TABLE 10–14. Woodruff Key (Fig. 10–34)

Dash Number	Nominal Key Size	A	B	D	E
H204	1/16 × 1/2	.0625	.500	.194	3/64
H304	3/32 × 1/2	.0938	.500	.194	3/64
H305	3/32 × 5/8	.0938	.625	.240	1/16
H404	1/8 × 1/2	.1250	.500	.194	3/64
H405	1/8 × 5/8	.1250	.625	.240	1/16
H406	1/8 × 3/4	.1250	.750	.303	1/16
H505	5/32 × 5/8	.1563	.625	.240	1/16
H506	5/32 × 3/4	.1563	.750	.303	1/16
H507	5/32 × 7/8	.1563	.875	.365	1/16
H606	3/16 × 3/4	.1875	.750	.303	1/16
H607	3/16 × 7/8	.1875	.875	.365	1/16
H608	3/16 × 1	.1875	1.000	.428	1/16
H609	3/16 × 1 1/8	.1875	1.125	.475	5/64
H807	1/4 × 7/8	.2500	.875	.365	1/16
H808	1/4 × 1	.2500	1.000	.428	1/16
H809	1/4 × 1 1/8	.2500	1.125	.475	5/64
H810	1/4 × 1 1/4	.2500	1.250	.537	5/64
H811	1/4 × 1 3/8	.2500	1.375	.584	3/32
H812	1/4 × 1 1/2	.2500	1.500	.631	7/64

10–19. Welding. — The representation of welds and notes for calling out welds should conform to the company practice where used. Some welding representations taken from aircraft drawings are shown in Fig. 10–35.

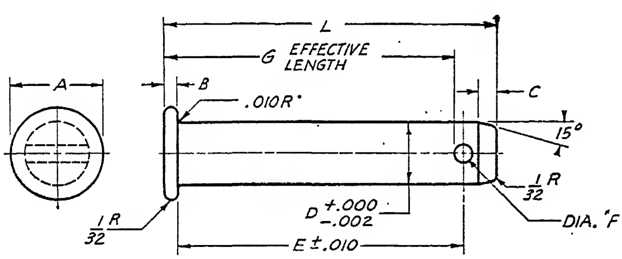


Fig. 10–31. Clevis Pin.

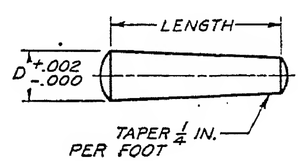


Fig. 10–32. Plain Taper Pin.

10–20. Miscellaneous. — There are a great many kinds of fastenings for which the latest dimensions and other data should be obtained from the Army and Navy Air Corps Standards and from manufacturers' lists. Some fastenings are illustrated and named in Figs. 10–36 and 10–37, which show some conven-

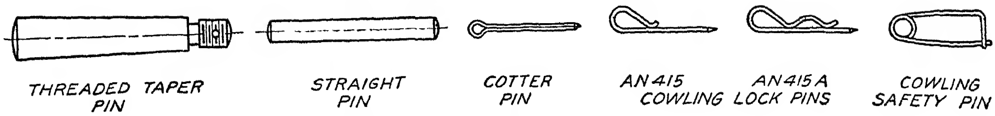


FIG. 10–33. Miscellaneous Pins.

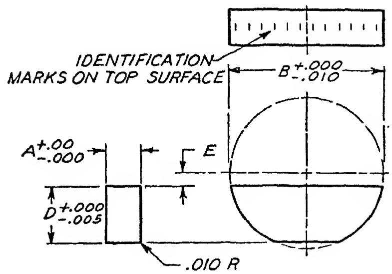


FIG. 10–34. Woodruff Key.

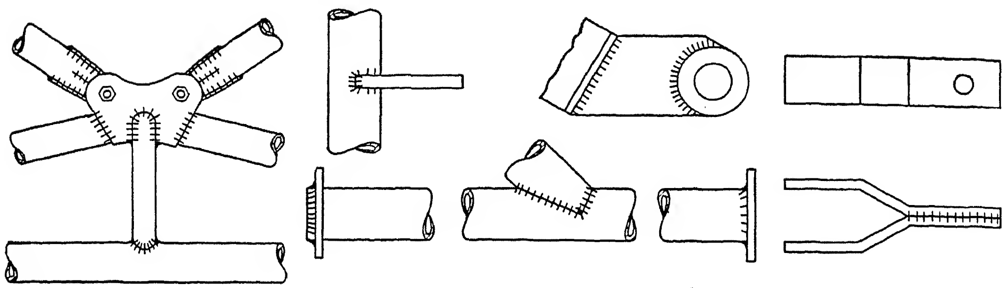


FIG. 10–35. Welding Symbols Applied.

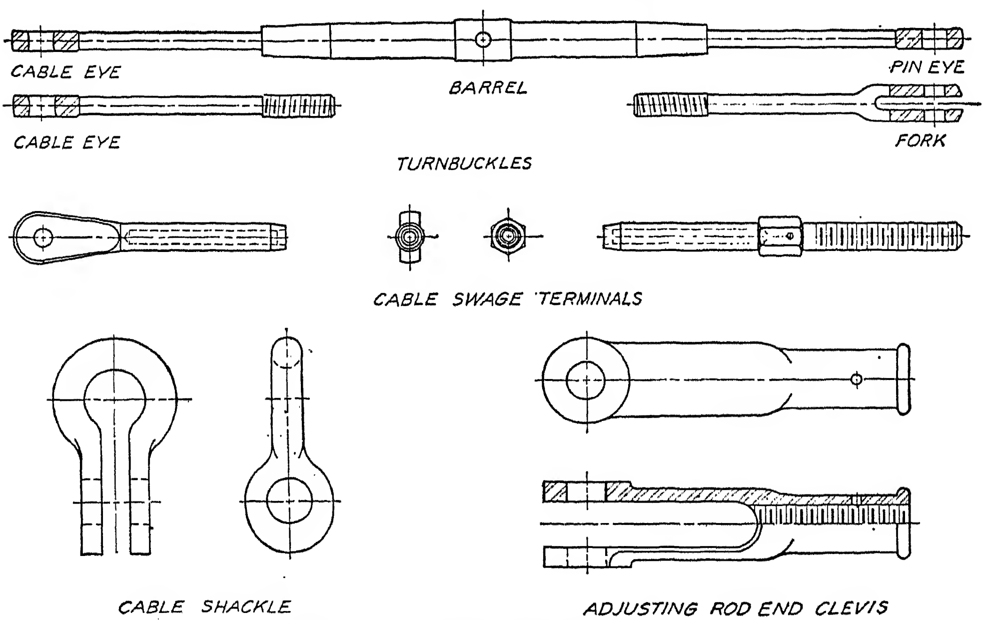


FIG. 10–36. Turnbuckles, Shafts, etc.

tional representations or symbols. Some structural and tubular shapes are shown in Fig. 10–38.

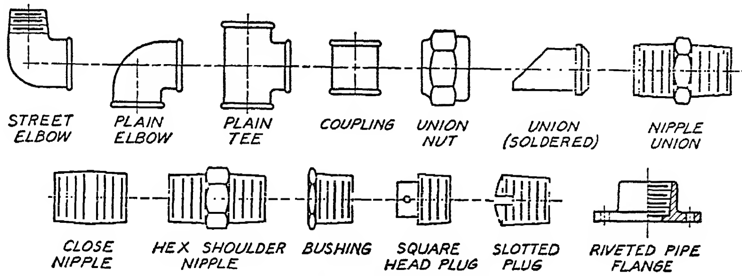


FIG. 10–37. Pipe Fittings.

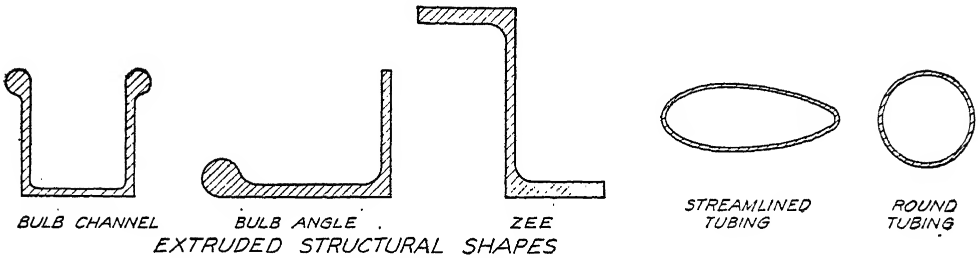


FIG. 10–38. Structural and Tubular Shapes.

10–21. PROBLEMS. — Read Art. 2–16 before starting these problems. Most of these problems are planned for one-quarter of a four-part layout (Fig. 2–31).

Probs. 10–1 to 10–3. Fig. 10–39. — Draw one or more turns of a *right-hand helix*. Prob. 10–1, dia. = $3\frac{1}{4}$, pitch = 4. Prob. 10–2, dia. = $2\frac{3}{4}$, pitch = 1. Prob. 10–3, dia. = 3, pitch = $1\frac{1}{2}$. Refer to Fig. 3–42.

Probs. 10–4 to 10–6 Same as Probs. 10–1 to 10–3 but for a *left-hand helix*.

Prob. 10–7. Draw profile of the threads for a $1\frac{1}{4}$ inch diameter screw. American (National) Fine Thread Series. Scale 25 times full size. Draw accurately to scale and put on all lettering as in Fig. 10–2 and give actual dimensions as they would be on the $1\frac{1}{4}$ inch screw.

Prob. 10–8. Fig. 10–40. — Draw profiles of American Standard, Square and Acme screw threads. Pitch = $\frac{7}{8}$ inch. Letter name of thread under each representation.

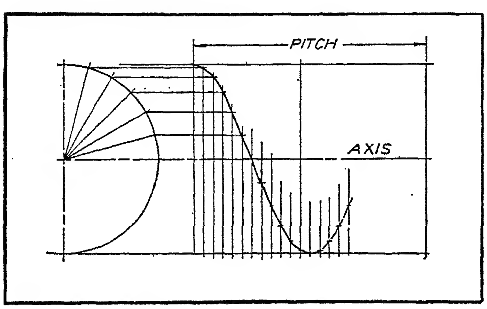


FIG. 10–39. Probs. 10–1 to 10–7.

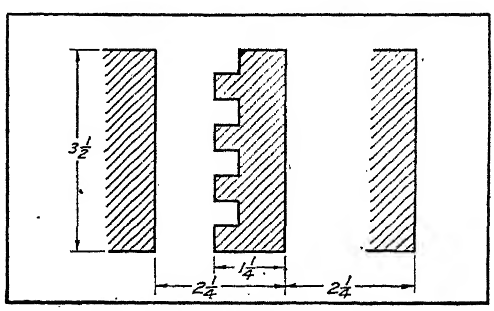


FIG. 10–40. Prob. 10–8.

Prob. 10–9. Fig. 10–41. — (Use 11 × 17 sheet) Draw the exterior of a square-threaded screw, 3¾ dia. and 5½ long, which enters a section of a square-threaded nut, Pitch = 1¾. It will be found convenient to draw one curve of each helix accurately on heavy paper or thin wood, cut out with a sharp knife, to make templets as shown in the figure which can be used for repeating the curves. For construction of helixes refer to Fig. 3–42.

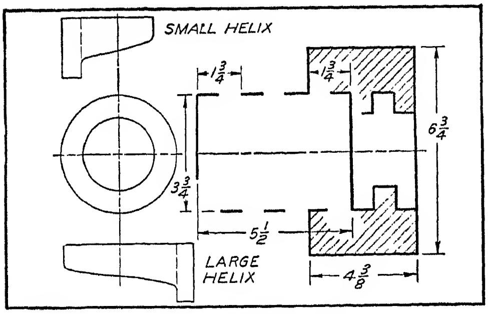


Fig. 10–41. Probs. 10–9 to 10–11.

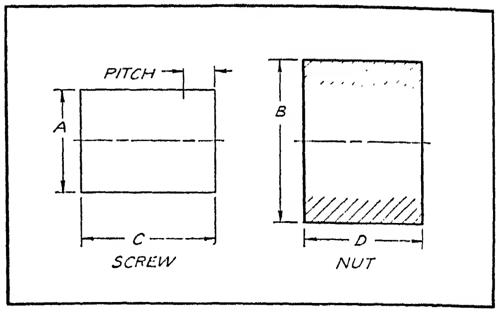


Fig. 10–42. Probs. 10–12 to 10–16.

Prob. 10–10. Same as Prob. 10–9 but for American Standard thread. Pitch = ⅞.
Prob. 10–11. Same as Prob. 10–9 but for Acme thread. Pitch = 1¾.
Probs. 10–12 to 10–16. Fig. 10–42. — Draw screws in elevation and section as indicated in the following table. Show form of thread. Draw pitch to scale. Use straight lines to represent helixes.

Prob.	A	B	C	D	Pitch	Kind of Thread
10–12	2¼	2¾	2¼	2¼	⅜	Am. Std. Single R.H.
10–13	1½	2½	2½	2	¾	Sq. Single R.H.
10–14	2½	3½	3	2	1	Acme Single R.H.
10–15	1¾	3	2	2	¼	Am. Std. Double R.H.
10–16	2⅜	2⅞	2½	2	⅜	Am. Std. Single L.H.

Prob. 10–17. Fig. 10–43. — Draw rods 3 inches long, threaded 1 inch on each end. Use different conventional representations of threads on each rod. See Figs. 10–9 and 10–10. On axis A make diameter 1⅛, on axis B, ⅞, on axis C, ⅝.
Prob. 10–18. Fig. 10–43. — On axes A, B and C draw elevations of threaded holes with end or plan views above. Use conventional representations. Axis A, dia. = 1, depth = 1½. Axis B, dia. = ¾, tapped through. Axis C, dia. = ⅝, depth 1¼.
Prob. 10–19. Fig. 10–43. — Same as Prob. 10–18 but draw sectional views instead of elevations.

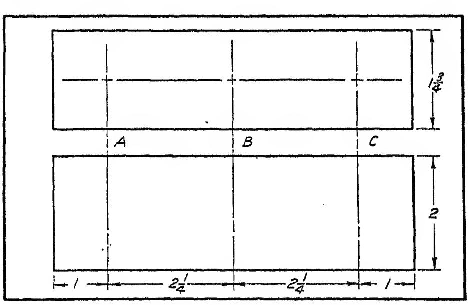


Fig. 10–43. Probs. 10–17 to 10–19.

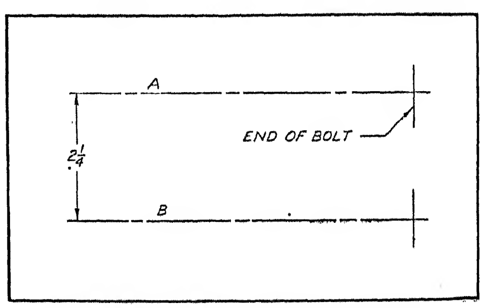


Fig. 10–44. Probs. 10–20 to 10–22.

Probs. 10–20 to 10–22. Fig. 10–44. — Draw an AN aircraft bolt and nut as specified. Show across flats on axis *A* and across corners on axis *B*.

Prob. 10–20. — Bolt dia. = 1, length = $4\frac{3}{4}$, thread = $1\frac{1}{8}$. Use plain nut AN315.
Prob. 10–21. — Bolt dia. = $\frac{3}{4}$, length = 5, thread = $\frac{15}{16}$. Use stop nut AC365.
Prob. 10–22. — Bolt dia. = $\frac{7}{8}$, length = $5\frac{1}{4}$, thread = $1\frac{1}{16}$. Use castle nut AN310.

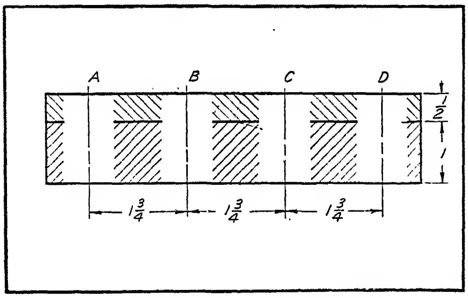


Fig. 10–45. Prob. 10–23.

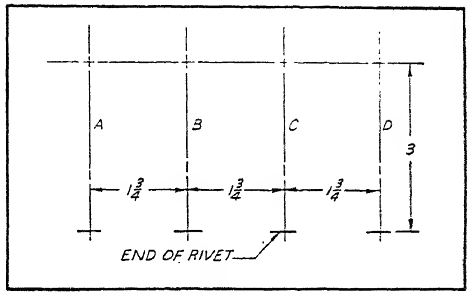


Fig. 10–46. Prob. 10–24.

Prob. 10–23. Fig. 10–45. — On axes *A*, *B*, *C* and *D*, draw machine screws as follows: flat head, oval head, round head and fillister head. Diameter $\frac{3}{8}$. Length to suit conditions.

Prob. 10–24. Fig. 10–46. — On axes *A*, *B*, *C* and *D*, draw elevations of rivets: countersunk head, type " D "; round head, type " AD "; flat head, type " A "; brazier head, type " DD ", respectively with top views above. Dia. = $\frac{3}{8}$. Length = $1\frac{1}{2}$.

CHAPTER XI

DIMENSIONING

11–1. Dimensions are used to tell sizes and locations of parts. In the practical application of dimensioning to aircraft parts and aircraft it is necessary to consider how the parts are made and how they are put together. This requires specification of materials, methods of forming, methods of machining, kinds of finish, accuracy of size, accuracy of fits, number of parts, etc.

11–2. Notation of Dimensioning (Fig. 11–1). — A *dimension line* is a light full line used to show the extent of a measurement, the amount of which is given by figures placed in a space left for that purpose.

Extension lines are light full lines used when it is necessary to extend from a line of a view. A space of $\frac{1}{32}$ inch to $\frac{1}{16}$ inch should be left between the extension line and the view. The extension line should extend about $\frac{1}{8}$ inch beyond the arrow-head. The crossing of dimension lines, extension lines, etc., should be avoided when possible. When necessary to have them cross, the crossing line should have a break (Fig. 11–1).

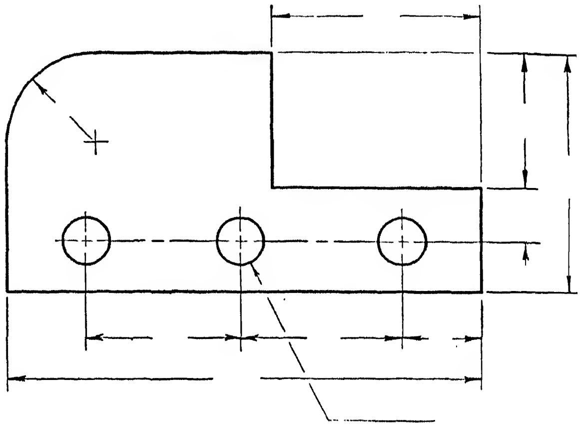


FIG. 11–1. Dimension and Extension Lines.

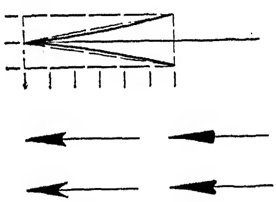


FIG. 11–2. Arrow-heads.

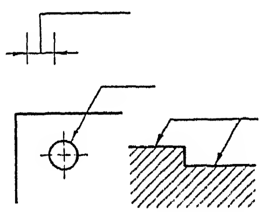


FIG. 11–3. Leaders.

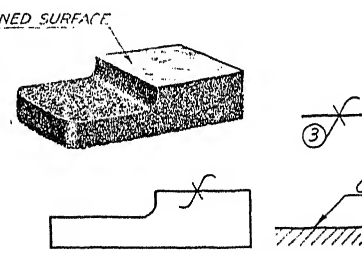


FIG. 11–4. Finish Marks.

Arrow-heads (Fig. 11–2) are placed on the ends of dimension lines and on one end of leaders or pointing lines. The American Standard proportion is to have the length about three times the spread. They are generally blacked-in or solid on aircraft drawings.

Leaders (Fig. 11–3) are light full lines used to indicate where notes and numbers apply to the parts represented. They are straight ruled lines generally at an angle.

Finish marks or symbols are used to indicate surfaces which are to be machined or finished (Fig. 11–4). When used with a circle, Fig. 11–4A, the number in the circle is an index number. The symbol and its meaning should be given in the title block as well as where it applies on the face of the drawing.

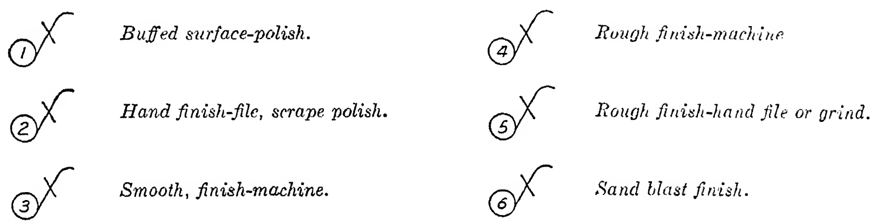


Fig. 11–4A.

11–3. Dimensional Units. — Dimensions are given in inches and NO INCH MARKS (″) are used. Dimensions on aircraft drawings are placed to read from the lower edge of the drawing (horizontally) regardless of the direction of the dimension lines. Engine drawings and certain accessories follow regular engineering practice and read from the lower and the right-hand sides of the sheet. The division line of a fraction should always be horizontal — never inclined. When decimals are used the position of the decimal point should be clearly indicated and should be made heavy.

Degrees, minutes and seconds may be indicated by the symbols, (°), (′) and (″) as $30° = 45' = 15''$, but abbreviations are preferred for clarity as 30° deg., 45 min., 15 sec.

11–4. Theory of Dimensioning. — The theory of dimensioning as developed by the author was originally published in the *Essentials of Drafting* and is now finding a place in various courses and textbooks where its importance is recognized by devoting a separate chapter to it instead of a set of " general rules " as was previously done.

The following statement is quoted from the *Essentials of Drafting:*

" Constructions can be separated into parts and these parts can then be divided into geometrical solids. Each of the solids can then be dimensioned and their relation to each other fixed." Thus, there are two kinds of dimensions:

1. Size Dimensions.
2. Location Dimensions.

11–5. Size and Location Dimensions. — Some of the elementary cases of size dimensions are illustrated in Fig. 11–5 which shows the prism, cylinder, cone, pyramid and sphere. Size dimensions are applied in Fig. 11–6.

Location dimensions are used to fix the positions of elementary parts in relation to each other or the location of groups of parts in relation to axes, contact surfaces, or other references. A few cases of location dimensions are illustrated in Fig. 11–7.

For a more complete treatment of the whole subject of dimensioning reference should be made to the author's *Drafting for Engineers*.

11–6. Placing Dimensions. — The purpose of the dimensions must be kept in mind at all times. Remember that it is the part or construction which is

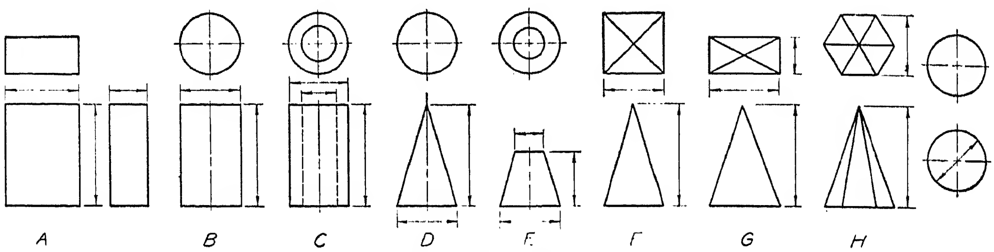


Fig. 11–5. Size Dimensions.

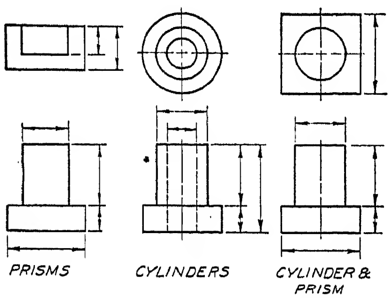


Fig. 11–6. Size Dimensions Applied.

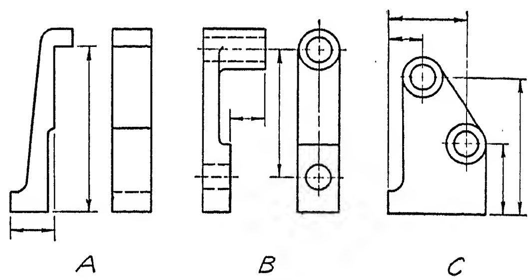


Fig. 11–7. Location Dimensions.

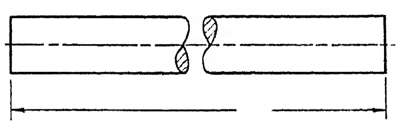


Fig. 11–8. Broken-out View.

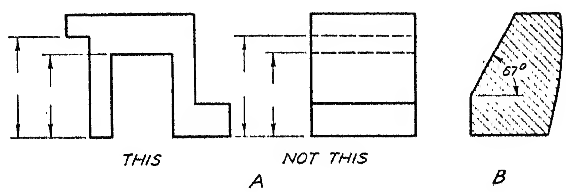


Fig. 11–9. Use Visible Lines.

being dimensioned and not the lines or views of a drawing. In general the clear space between dimension lines should be about 5/16 inch so that the dimensions may be placed without crowding. Dimensions should be placed outside the views when possible and preferably to the right and below the views. Do not place a dimension line at or near the intersection of two dimension lines. In general do not break the dimension line when it is used with a broken out view (Fig. 11–8). Company practice should be followed in all cases. Dimensions should be applied to visible lines rather than hidden lines (Fig. 11–9 at *A*). They

should be kept out of sectioned areas when possible but if necessary to place them within the area a space should be left for the dimension (Fig. 11–9 at *B*).

Do not try to complete the dimensioning on one view before considering the other views. Think of the part and how it is to be made — not the drawing.

Draw all the extension and dimension lines first, put on the arrow-heads, and then fill in the dimensions and add all necessary notes.

Consecutive dimensions should be placed in a continuous line (Fig. 11–10). Sometimes conditions require the less desirable *staggered* arrangement of Fig. 11–11 to avoid crowding. *Progressive dimensions* from a common base line should be given as in Fig. 11–12 unless there are special conditions which require some other arrangement. The arrangement of Fig. 11–12 is called base-line

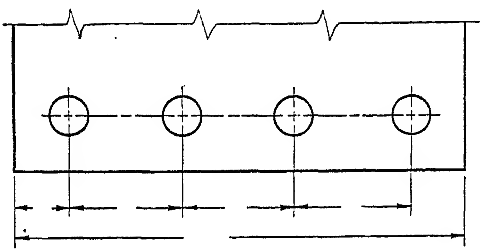


Fig. 11–10. Consecutive Dimensions.

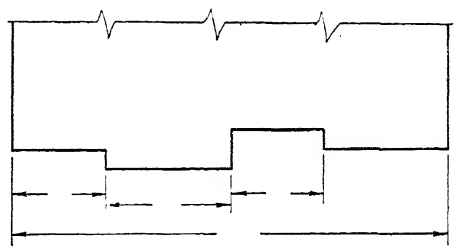


Fig. 11–11. Staggered Dimensions.

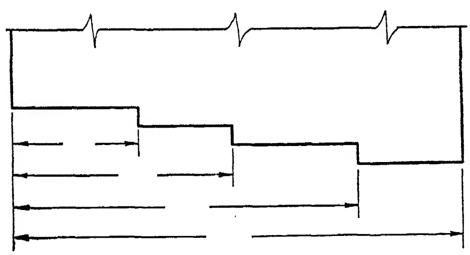


Fig. 11–12. Progressive Dimensions.

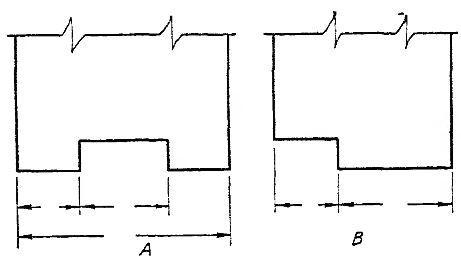


Fig. 11–13. Over-all Dimensions.

dimensioning and is used when limits are specified. *Over-all dimensions* should be given where necessary [when it is important that they be held (Fig. 11–13 at *A*)]. When the intermediate dimensions are critical and the over-all dimension is NOT important, the over-all dimension is not given (Fig. 11–13 at *B*).

11–7. Dimensioning Circles, Arcs, etc. — Some methods of dimensioning circles, arcs and curves are shown in Fig. 11–14. The dimension for a diameter should be followed by the letter *D* (or the abbreviation *DIA.*) except when it is evident on the drawing. Some companies use the letter *D* or the abbreviation *DIA.* after every dimension for a diameter without exception. The dimension for a radius should always be followed by the letter *R*. The diameter of a complete circle is preferred to the radius, the latter being used for arcs only. When necessary the center for an arc should be located with reference to a surface, axis,

or a combination of both. For small arcs, fillets and corner radii, the centers need not be located, and the radii may be placed outside the view as indicated. The note *break corner* means that the sharp corner is to be removed. The dimension line for an arc should always pass through the center. For other curves, the construction may be shown (see Chapter III), a templet may be specified, the

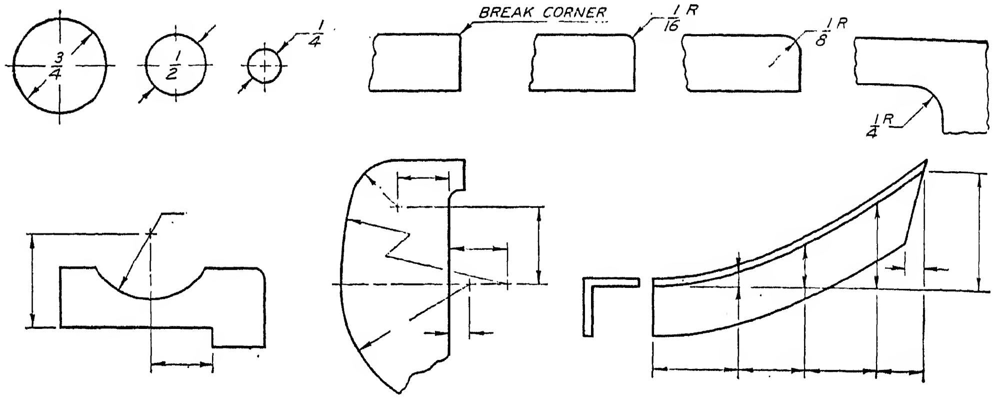


FIG. 11-14. Circles, Arcs and Curves.

curve may be shown full size or complete dimensions may be given as indicated for the curve in Fig. 11-14.

11-8. Dimensioning Angles and Tapers. — Angles may be dimensioned by giving the number of degrees included between the two sides, by figured dimension, by the taper per foot or per inch, etc. (Fig. 11-15). Where fillets or rounds

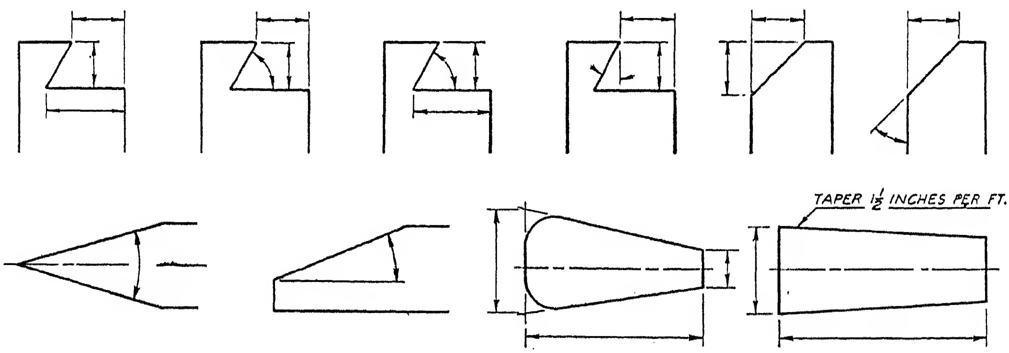


FIG. 11-15. Angles and Tapers.

occur extension lines should be continued to intersect as shown. Regular dimensions rather than degrees are preferred when they can be used. Tapered bolts, pins, shafts, etc., may be specified in several ways, such as: the diameter at one end, the length, and the taper per foot; the large and small diameters and the length; one diameter, the length and the American Standard taper number (ASA B5). The " taper per foot " of a round section means the difference in

diameters for one foot of length. " Slope " is the difference in radii for one foot of length. For very accurate work special methods of dimensioning angles or tapers may be necessary.

11–9. Limits and Tolerance. — When dimensions are given without any indication of accuracy, *nominal size* is implied and the *actual measurement* of the part may be greater or less than the specified amount. A great many dimensions are nominal dimensions. When common fractions are used for machined parts the variation may be taken as not more than 1/128 inch over or under the basic size for dimensions of 1/4 inch or less, and not more than 1/64 inch over or under the basic size for dimensions of more than 1/4 inch. Decimals are used when greater accuracy is required. The necessity for accuracy is important when it implies accurately fitted mating parts. Exact dimensions are, of course, impossible. Therefore, in order to have parts fit and mate together properly certain limitations must be set up. Thus a *basic size*, or theoretically exact basic dimension, is followed by upper (+ plus) and lower (− minus) limits such as $2.750 \begin{array}{l} + .0025 \\ - .0015 \end{array}$ which the workman must not exceed. The difference between these limits is called *tolerance*, and represents the amount of error permitted or tolerated.

Limits should be given for only those dimensions which require them because of the particular relation of fitted parts. Giving limits for all dimensions for a given part frequently makes the specification ambiguous — several successive dimensions of portions of a shaft of various diameters together with the over-all dimension. The separate dimensions might be within the limits but the over-all might not be. The correct method in such a case is to give all the measurements from a single surface or reference (base line dimensioning, Fig. 11–12) or one of the separate dimensions, preferably at the end, may be omitted (Fig. 11–10).

A drawing with limiting dimensions is reproduced in Fig. 11–16.

The practice of the particular company where the drawings are made should be ascertained and followed in the matter of limits and tolerance.

11–10. Finishes and Operations. — When machine or other kinds of finishes are required they should be specified on the drawing (Fig. 11–17) by symbols, by a note near the views of the part, or in a list provided for the purpose. Extra material is provided on castings, forgings, etc., to be removed in the machining process.

The various kinds of finish should be studied in books on machine shop practice. The following terms are in general use: FINISHED ALL OVER, FILE FINISH, ROUGH FINISH, CHIP, SAND BLAST, PICKLE, SCRAPE, LAP, GRIND, POLISH, BURNISH, BUFF, HONE, SPOTFACE, COUNTERBORE, COUNTERSINK, CORE, BORE, DRILL, REAM, BROACH, TAP, PLATE, BEVEL, CHAMFER, DIMPLE, RIVET, SOLDER, BRAZE, WELD, CADMIUM PLATE, ANODIC TREATMENT, etc.

11–11. Materials. — Some of the materials used in the manufacture of aircraft are listed below. Specifications are listed in a design data book by most

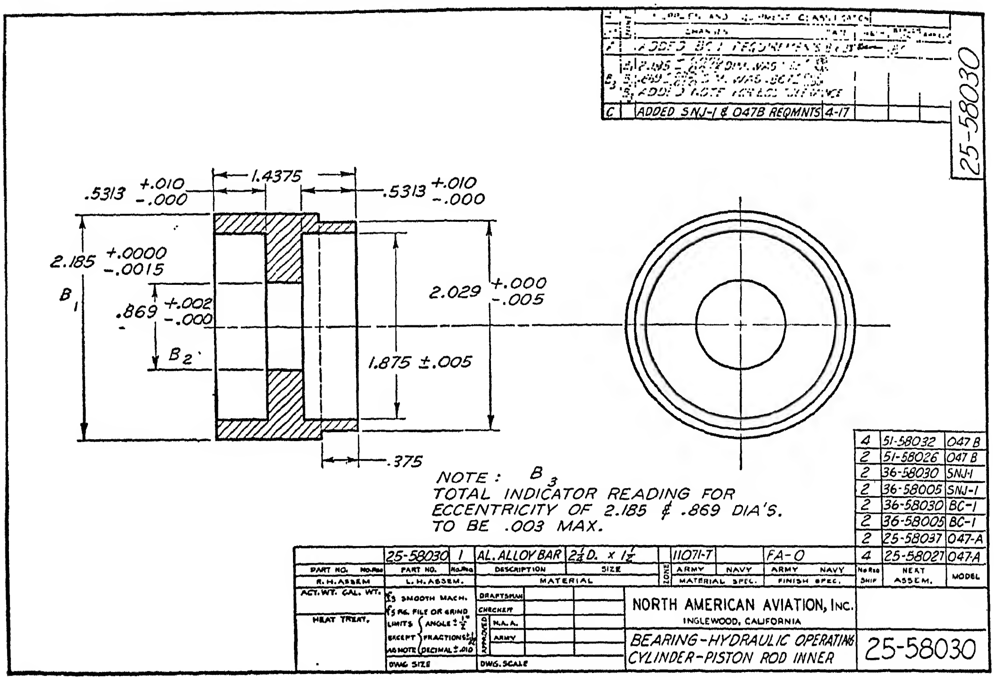


FIG. 11–16. Limits. (*North American Aviation, Inc.*)

companies. Such a book contains up-to-date information under headings of Material, Federal, Air Corps, Navy, Uses and Remarks, from which is obtained data to be placed on drawings. The aircraft draftsman and engineer must seek at all times to be informed on available materials and the purposes for which they can be used.

Aluminum Alloys
Brass
Bronze
Cable-Electrical
Casing-Control
Cement
Cloth
Copper
Dope
Duck
Felt
Fiber
Glass
Glue
Kapok
Lead
Leather
Magnesium Alloys
Neoprene
Nickel Alloys
Packing
Processes
Rubber
Steel
Tape
Thread and Cord
Transparent Plastic Sheet
Wood

11–12. Holes — Drilled, Reamed, etc. — Some notes for drilled holes are given in Fig. 11–18. The depth of a drilled hole indicates the cylindrical part as at (A). Unless conditions prevent, *drill for ream* should extend beyond depth of ream a distance equal to the diameter as at (F). It is possible but not desirable to drill for ream as at (G). The angle of countersink is measured by the angle included between the sloping sides, and the diameter of the countersink is measured at the surface of the material. The form of notes in Fig. 11–18 indi-

cates common aircraft practice which gives the operation first and then the dimension, but practice is not uniform as shown by the variations in Fig. 11–19.

Some examples of notes for holes and finishes from American Standard Drafting Practice (ASA Z14.1) are given in Fig. 11–20.

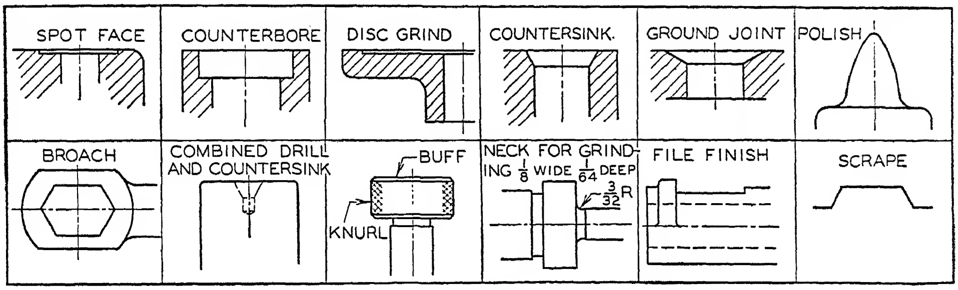


Fig. 11–17. Finished Surfaces.

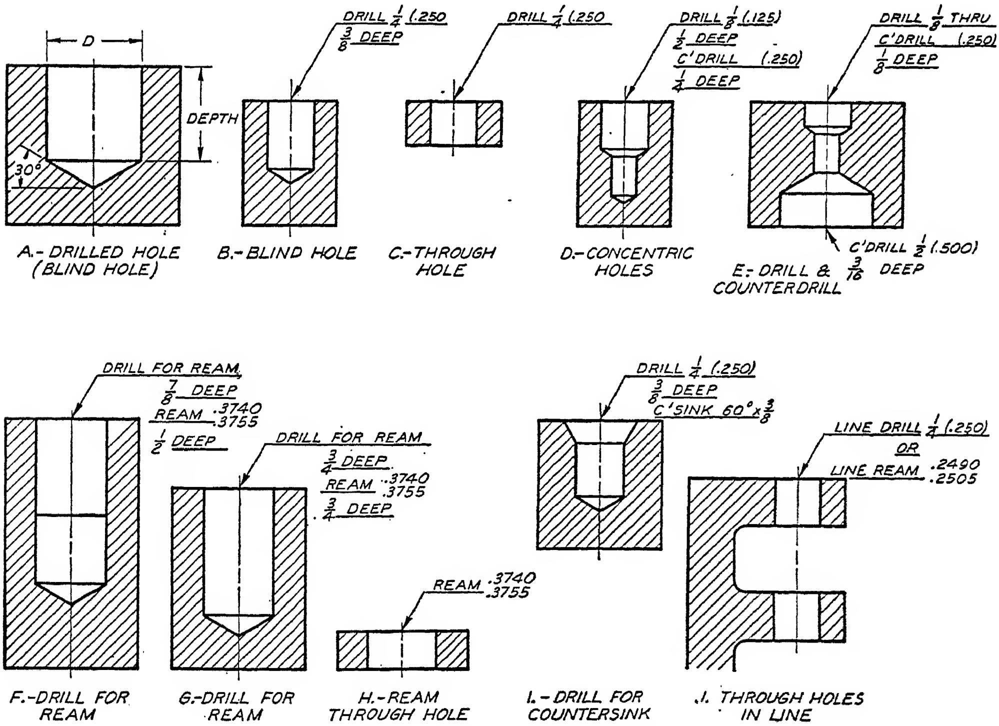


Fig. 11–18. Drilled and Reamed Holes.

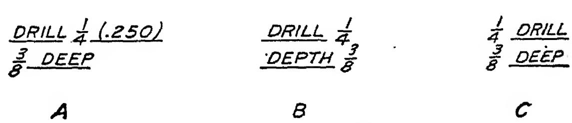


Fig. 11–19. Notes.

11–13. Spotface and Backface (Figs. 11–21, 11–22 and 11–23). — When it is necessary to have a finished spot on an otherwise unfinished surface spotfacing or backfacing (backspotfacing) may be used. North American Aviation, Inc., describes their spotfacing practice as follows: " (1) ' Spotface ' denotes a finished spot of given diameter, on an unfinished surface, around a hole, and made

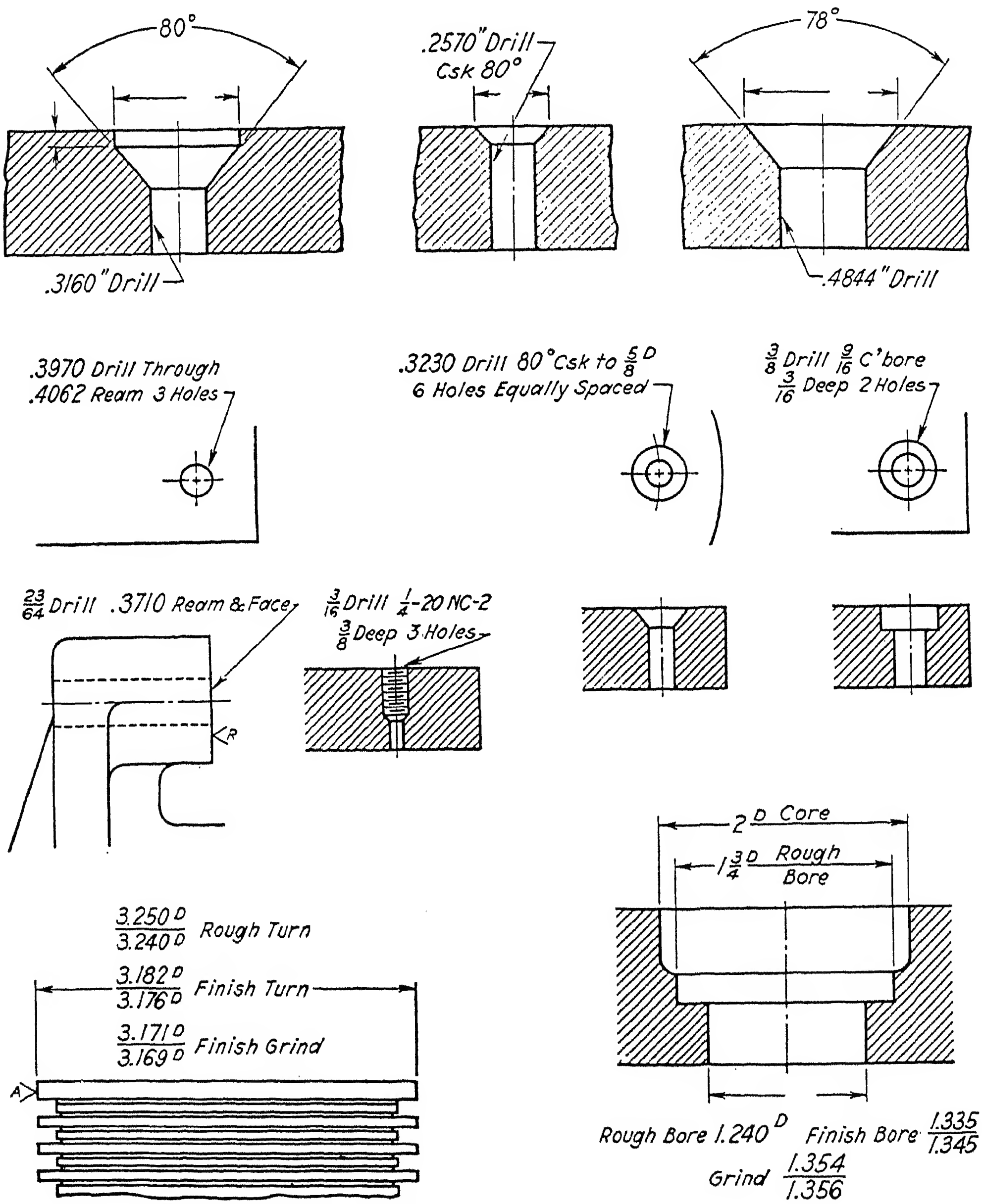


FIG. 11–20. American Standard Notes.

with a spotfacing tool. When ' Spotface ' is called for, the pattern maker applies finish allowance at his option, but '*f*' marks should be omitted from the drawing. In spotfacing, only sufficient material is removed to make a level surface where bolt length accuracy is not required. The limit of accuracy of spotfacing to a thickness is ±.010. (2) When close dimensions must be adhered to, the ' Spot-

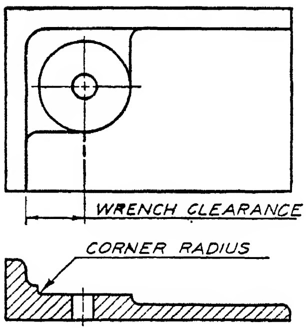


Fig. 11–21. Spotface.

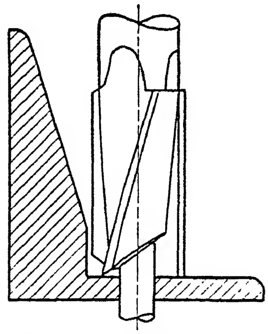


Fig. 11–22. Spotface.

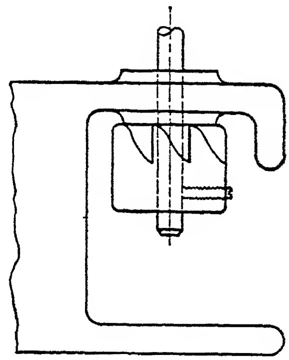


Fig. 11–23. Backface.

face ' note cannot be used, but dimensions and machine finish notes should be shown. (3) When ' Spotface ' is called for on top of a boss, the diameter of the spotface tool should be greater than the diameter of the boss. (4) In order to minimize the possibility of fracture, specify the spotface corner radii according to the following table:

Table of Corner Radii:

Diameters to 3/4	.010 Min. Radius
3/4 to 1 1/2 Incl.	.025 Radius
Over 1 1/2 Dia.	.032 Radius

" (5) Drawing Note.

DRILL #10 (.1935) – 2 HOLES
SPOTFACE 1/2 DIA.
.025 CORNER RADIUS ON CUTTER

" (6) Table of standard bolt spotface diameters:

Bolt Size	#6	#8	#10	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4
Spotface	7/16	1/2	1/2	9/16	5/8	3/4	3/4	15/16	1 1/8	1 1/4	1 3/8

" (7) Other diameters may be used in special cases."

Wrench clearance and spotface corner radii should be provided (Fig. 11–21). Fillets requiring the use of long spotface pilots (Fig. 11–22) are undesirable because of likelihood of tool breakage. Backspotfacing (Fig. 11–23) is difficult

and undesirable. It requires the securing of a spotfacing tool to a spindle which has been put through the hole.

11–14. Application of Dimensions. — The following list includes much that is basic practice in the aviation industry. Some variations can be expected and the practice of the particular company where employed should be learned.

1. Dimensioning and notes should be so complete that all needed information can be obtained without scaling or calculating.
2. Dimensions should be placed for the convenience of the workman, should be the dimensions he needs and in the position where needed.
3. Dimensions on a view should be related to a definite edge. Do not expect close or accurate work when dimensions are related to arbitrary or non-existant lines.
4. Important features should be dimensioned carefully to give proper application of limits and clearances.
5. Center lines, view lines and extension lines should not be used as dimension lines. A dimension line should not appear as a continuation of a view line.
6. All material should be dimensioned by the decimal or fractional equivalent and not by gage number.
7. All drawings of surfaces, such as panel, aileron, and vertical and horizontal tail surfaces, should have the areas shown thereon.
8. Do not give angles unless they are required for the proper making or using of the part. Regular dimensions are better.
9. Parts which are bent to shape should have the dimensions given to the mold lines and on the outside (Chapter XIII).
10. In general, do not repeat a dimension.
11. Give " over-all " or necessary equivalent dimensions.
12. Give all necessary center distances.
13. Many standard details, materials and parts do not require complete dimensioning — a note or specification number is sufficient in such cases.
14. Forging drawings are preferred full size when feasible. A parting line (P.L.) should be indicated by showing draft from it on each side but it should not be dimensioned. Minimum dimensions should be given (to exclude draft allowance). The standard draft angle is 7° around all exterior surfaces. Interior draft such as holes, etc., should have 10° draft.
15. The dimensioning requirements of a drawing are governed by the purpose to be served. The purpose must be understood, and the practices of the particular company must be known. To this must be added the judgment developed by experience.

11–15. Sheet Metal Parts. — General principles of dimensioning apply to sheet-metal parts but there are certain exceptions which are explained in Chapter XIII.

11–16. PROBLEMS. — Dimensioning is one of the most important parts of drafting and time will be well spent in the study and application of the principles

as set forth in this chapter. Understand the reason for every dimension. Distinguish between *size dimensions* and *location dimensions*. Where printed scales accompany the figure, measurements may be obtained with the dividers and scale as shown at A and B in Fig. 11–24, where the reading at B shows a desired dimen-

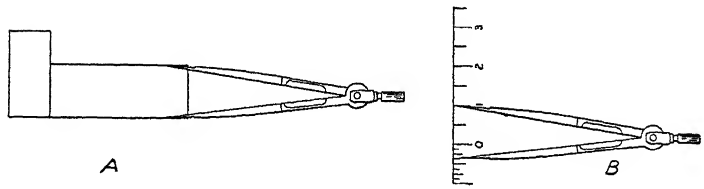


FIG. 11–24. Measurements.

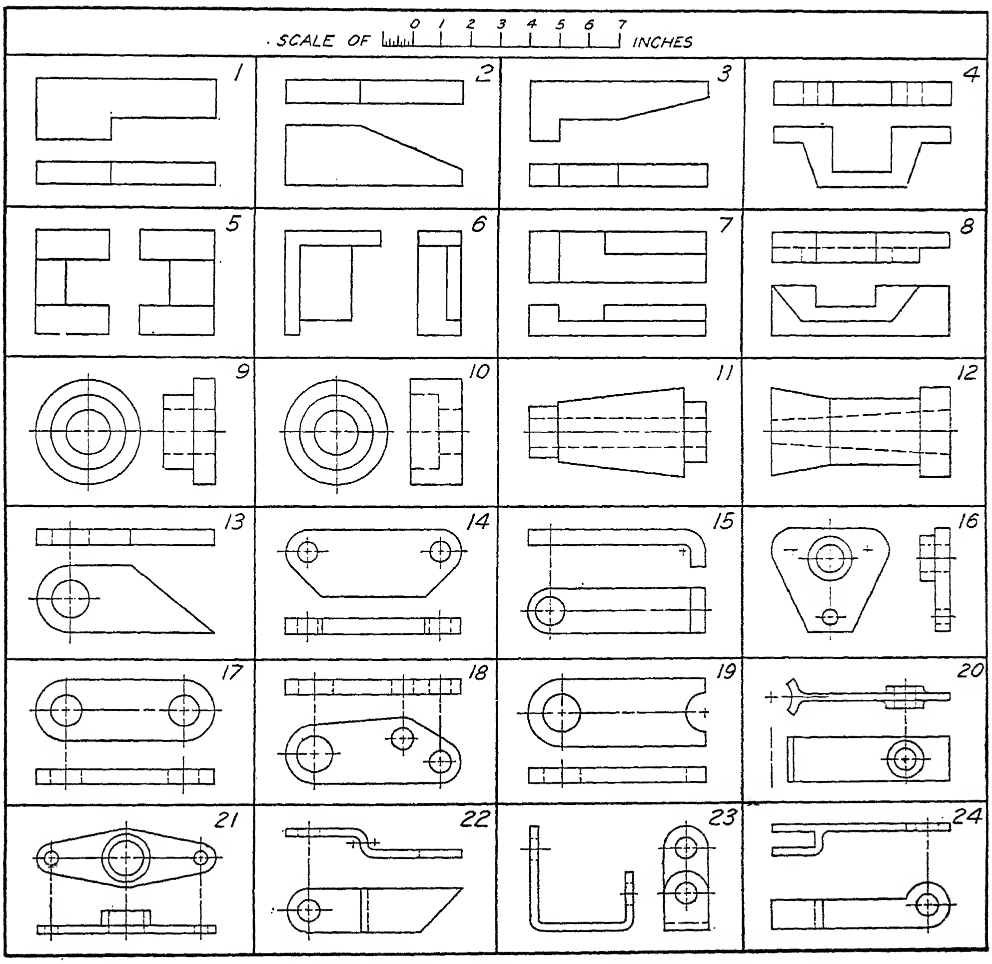


FIG. 11–25. Probs. 11–1 to 11–24.

sion to be 1⅜. A full size scale is then used to lay off this measurement on the drawing. Other dimensions are obtained in the same way. Follow the procedure given in Art. 11–6.

Read Art. 2–16 before starting these problems. Most of these problems are planned for one-quarter of a four-part layout (Fig. 2–31).

Probs. 11–1 to 11–24. Fig. 11–25. — Draw the views shown, determining measurements with dividers and graphic scale. Put on dimension lines, scale your drawing and fill in the dimensions. Finished surfaces to be assumed or specified by the instructor.

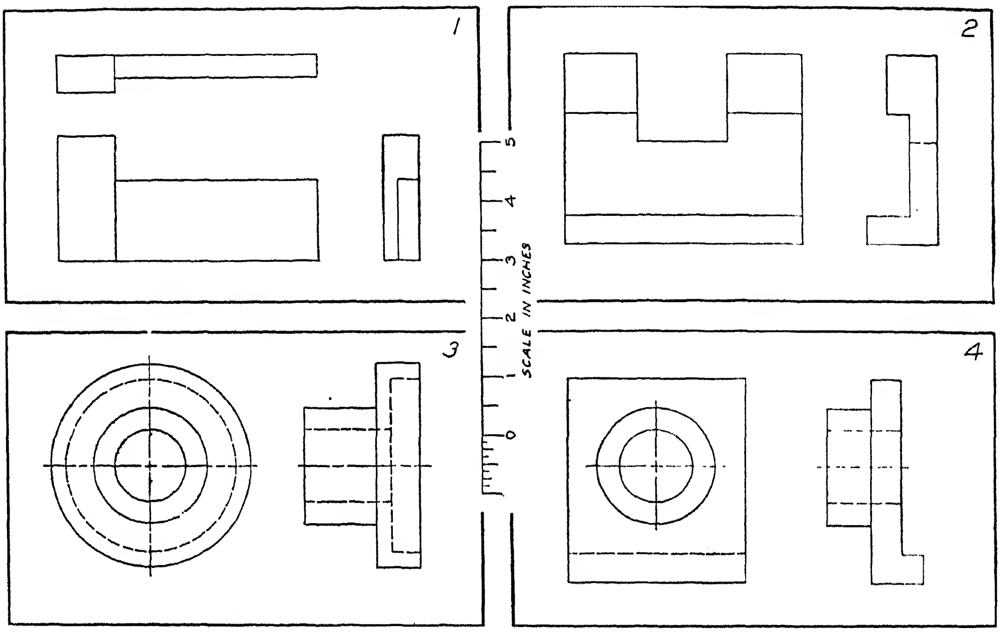


Fig. 11–26. Probs. 11–25 to 11–28.

Probs. 11–25 to 11–28. Fig. 11–26. — Draw the views shown, determining measurements with the dividers and graphic scale. Put on dimension lines, scale your drawing to the nearest ⅛ and fill in the dimensions. Prob. 11–25, Space 1, SPACER; Prob. 11–26, Space 2, FORMER; Prob. 11–27, Space 3, END COVER; Prob. 11–28, Space 4, BEARING. Finished surfaces are to be assumed or specified by the instructor.

Probs. 11–29 and 11–30. Figs. 11–27 and 11–28. — Sketch the necessary views of each piece. Place dimension lines on the views and indicate location dimensions by letter L with subscripts as L_1, L_2, etc., to indicate the order in which the dimensions are placed on the views. In like manner use S_1, S_2, etc., for size dimensions.

Probs. 11–31 to 11–54. Fig. 11–25–1 to 11–25–24, respectively. — Same directions as for Probs. 11–29 and 11–30.

Probs. 11–55 to 11–83. Figs. 6–18 to 6–27. — Same directions as for Probs. 11–29 and 11–30.

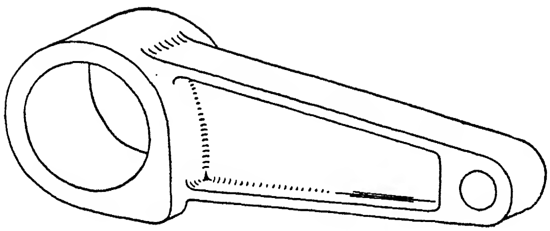


FIG. 11-27. Prob. 11-29.

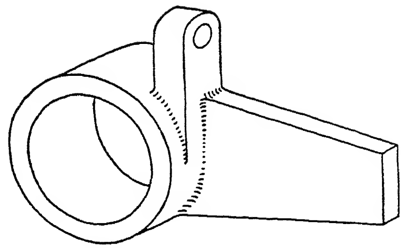


FIG. 11-28. Prob. 11-30.

CHAPTER XII

AIRCRAFT DETAILS

12–1. Aircraft parts are made of many different materials and in many forms or shapes to meet the many different uses for which they are required. As mentioned in previous chapters there are large numbers of standard parts which are in general use. Many other parts are similar but vary in dimensions, methods of forming, installation, etc. Army and Navy (AN) Standard parts can be specified by number as can certain company and commercial standard parts but there are many other details which must be completely described by regular detail working drawings.

12–2. Detail Drawings. — A detail drawing (Fig. 12–1) shows a single part and gives all the information to completely describe the shape, size, material, method of finish, number required, etc. Such a drawing must not depend upon any information other than what is shown. The number and kind of views, scale, and other treatment are determined by what is necessary to describe the shape and to contain the dimensions and notes.

Separate detail drawings of the parts facilitate manufacture. They increase the potential use of the parts since they do not have to be separated from an assembly. This permits the shop to fabricate a number of parts at the same time in different sections of the plant.

12–3. Arrangement of Views. — The principal views of an aircraft part should always be arranged in conformity with " third angle " projection as explained in Chapter V. Extra part views, full or sectional and same size or enlarged may be placed in other positions but explanatory notes should always be given. In general, parts should be drawn in the same position they occupy in the completed airplane, headed towards the left hand. The left-hand parts are drawn where there are both right- and left-hand parts.

12–4. Scale. — The scale should be such as will permit a clear description of the shape and proper dimensioning. The scales ordinarily used on aircraft drawings are given in Art. 9–7.

12–5. To Make a Pencil Drawing. — Consider the part to be drawn, the number, kind and treatment of views, and select a suitable scale. Parts have certain determining lines, axes, surfaces, and centers which should be used to locate and work up the views. A study of the door catch bracket of Fig. 12–2 (Space 1) will show (Space 2) that the front view has one main base line and one main center line, the top view has two center lines, and the right-side view has a base line and a center line. These lines have been drawn (in the order as numbered) in Fig. 12–2 (Space 2) and dimensions have been laid off for the main

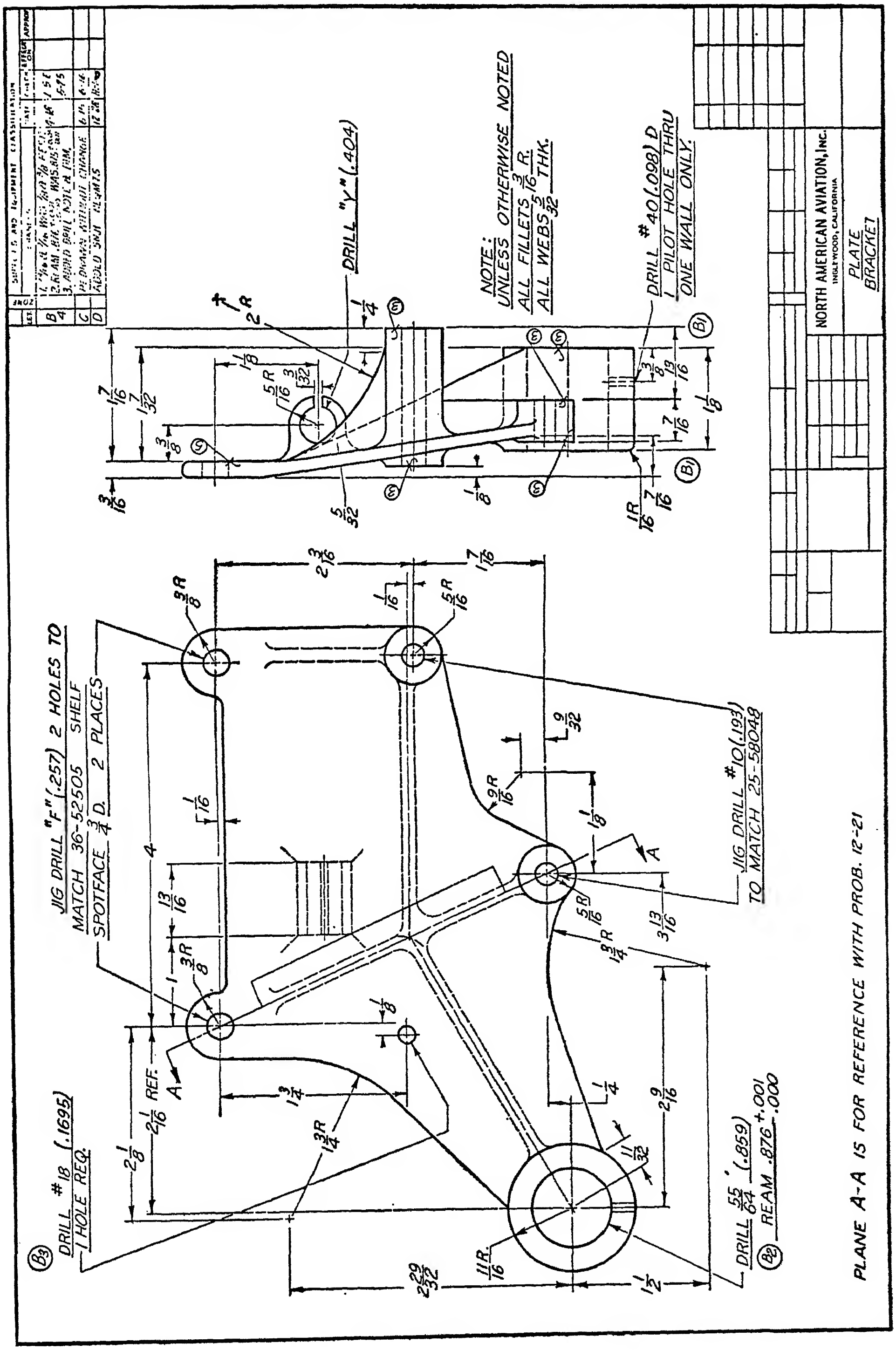


FIG. 12-1. A Detail Drawing.

outline (short horizontal and vertical marks.) Preliminary lines have been drawn in Space 3 and more dimensions have been marked off. The views have been blocked-in in Space 4 and completed in Space 5. In Space 6, necessary erasures of construction lines have been made, the lines of the views have been brightened, dimension lines have been drawn and the drawing is ready for dimensions and notes.

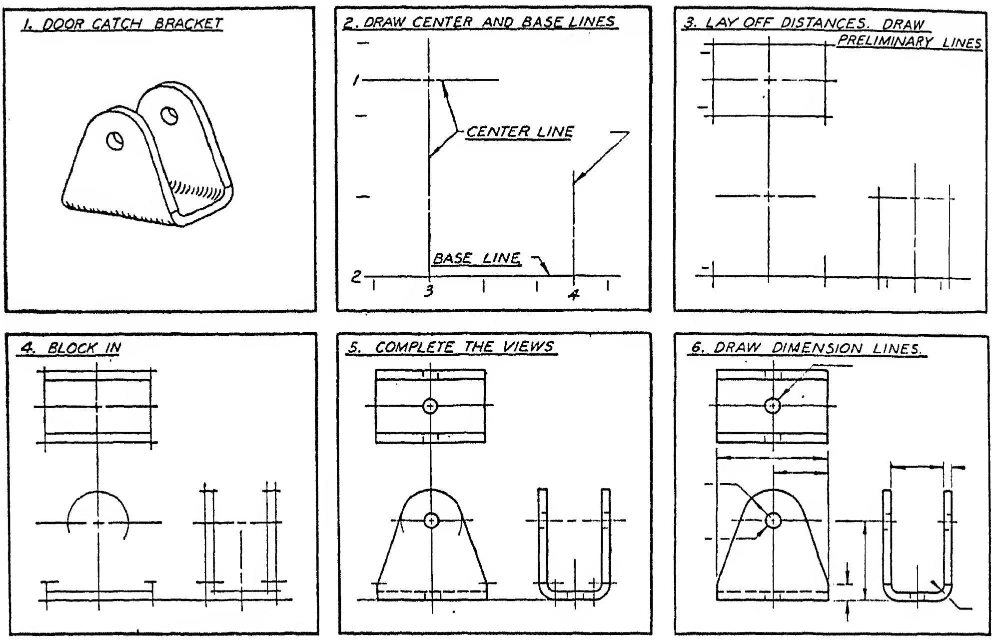


FIG. 12-2. To Make a Drawing.

12-6. The general order of procedure for a pencil drawing on drawing or tracing paper, or pencil tracing cloth is given in the following list.

1. Center and base lines.
2. Preliminary lines.
3. Blocking-in lines.
4. Straight lines.
5. Large circles and arcs.
6. Curved lines.
7. Small circles and arcs.
8. Section lines.
9. Dimension and extension lines.
10. Arrow-heads, dimensions and notes.

12-7. Tracing. — Pencil drawings may be traced in pencil on tracing paper or pencil tracing cloth or they may be traced in ink. The dull side of tracing cloth is generally used. The cloth should be placed over the pencil drawing, carefully smoothed, and fastened to the drawing board. To be sure of good ink lines rub over the surface with finely powdered chalk or pounce and wipe clean.

12-8. The general order of procedure for tracing on either paper or cloth is given in the following list.

1. Main center lines.

FULL LINES

2. Small arcs and circles.
3. Large arcs and circles.
4. Irregular curved lines.
5. Horizontal lines.
6. Vertical lines.
7. Slant lines.

HIDDEN LINES

8. Small arcs and circles.
9. Large arcs and circles.
10. Irregular curved lines.
11. Horizontal lines.
12. Vertical lines.
13. Slant lines

OTHER LINES

14. Center lines.
15. Extension lines.
16. Dimension lines.
17. Arrows and figures.
18. Section lines.
19. Border lines.

Kinds of lines are illustrated in Figs. 2–20 and 2–21. Where erasures are necessary use a pencil eraser as an ink (or abrasive) eraser will destroy the surface.

12–9. Airplanes. — It is not necessary to learn every detail of the many types of airplanes as modifications are constantly improving the accepted general types — the monoplane (Fig. 12–3) and the biplane (Fig. 12–4). The monoplane

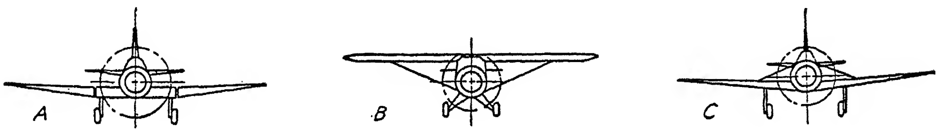


Fig. 12–3. Monoplane.

may be of the cantilever type with no external bracing (Fig. 12–3 at *A*) or semi-cantilever type with struts which are in tension during flight and compression when at rest. (Fig. 12–3 at *B*, high wing, or at *C*, low wing.) The biplane (Fig. 12–4) has two wings with interplane members (called struts, even though they are sometimes in tension) which are vertical, or nearly vertical, between the upper and lower wings. Wires and cables are used to take certain loads in biplanes, as the flying or lift wires emphasized in Fig. 12–4 at *A* which carry the load during flight and the anti-lift or landing wires emphasized at *B*. Other flying and landing wires (called external drag and anti-drag wires) are inclined rearward in some airplanes to take the drag load.

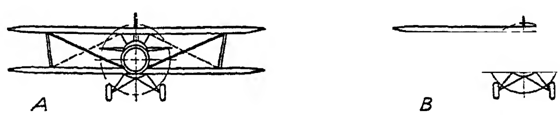


Fig. 12–4. Biplane.

The parts of an airplane are illustrated and named in Fig. 9–1 and the same chapter (Chapter IX) contains the nomenclature for aeronautics.

12–10. Monoplanes. — The two-place high-wing monoplane illustrated in Fig. 12–5 is the " Cadet " made by the Interstate Aircraft and Engineering Corporation, El Segundo, California. It is powered by a Continental engine. It has a steerable tail wheel, hydraulic brakes, a semi-cantilever wing of solid spruce spars, aluminum alloy ribs of the rigid truss type and aluminum alloy leading edges, fuselage of welded chrome molybdenum seamless steel tubing incorporating Warren type-trussing, ailerons of semi-friese-type and an integral fin. Wing area, 173.8 sq. ft. Span, 35.5 ft. Gross weight, 1200 pounds. Maximum speed,

107 m.p.h. Cruising speed, 100 m.p.h. Rate of climb, 650 ft. per minute. Service ceiling, 15,000 ft.

The two-place low-wing monoplane illustrated in Fig. 12–6 is the " Ercoupe " made by the Engineering and Research Corporation, Riverdale, Maryland. It is powered by a Continental A-65 engine. The Ercoupe structure is all metal,

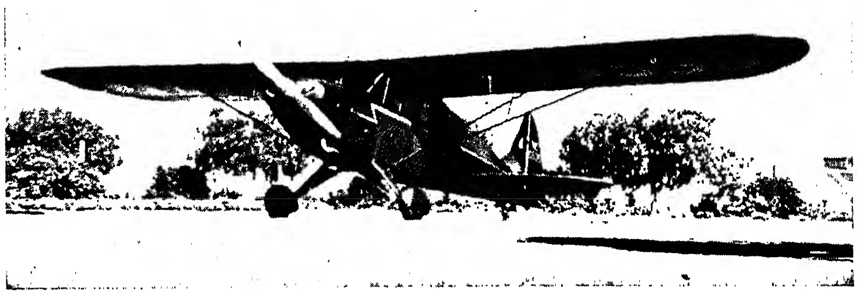


FIG. 12–5. High-wing Monoplane. (Interstate Aircraft and Engineering Corporation.)

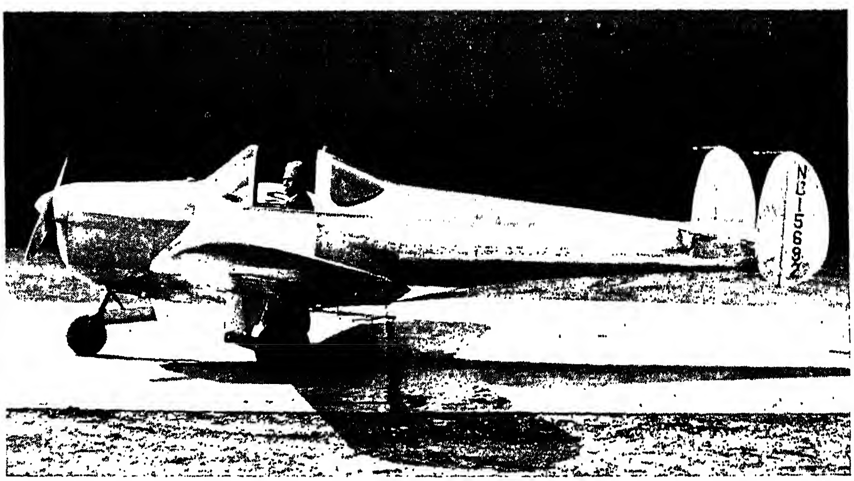


FIG. 12–6. Low-wing Monoplane. (Engineering and Research Corporation.)

including the covering of all but outer wing panels. Wings and tail surfaces are formed fully cantilever. Equipped with internally expanding hydraulic brakes. Wing area, 142.6 sq. ft. Span, 30 ft. Gross weight, 1175 pounds. Maximum speed, 117 m.p.h. Cruising speed, 105 m.p.h. Rate of climb, 800 ft., first minute. Service ceiling, 14,000 ft.

The model 339 Brewster Fighter illustrated in Fig. 12–7 is a single place land type mid-wing monoplane powered with alternately a Wright G100 or G200 Cyclone engine and is made by Brewster Aeronautical Corporation, Long Island City, New York.

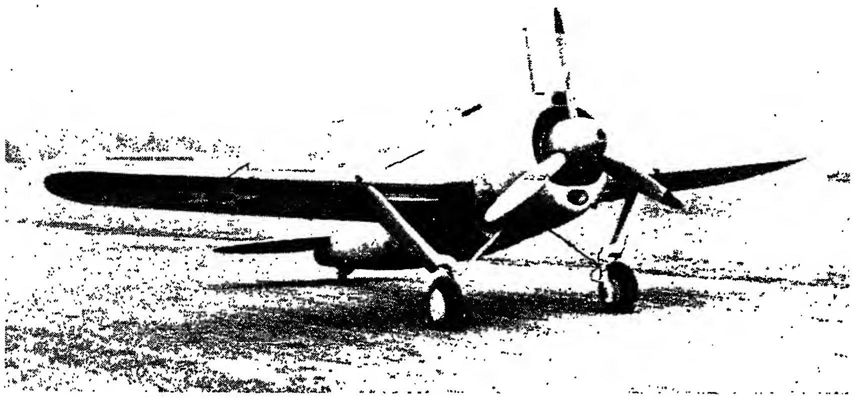


FIG. 12–7. Midwing Monoplane. (Brewster Aeronautical Corporation. Official Photograph — U. S. Navy.)

" The airplane may be equipped to carry four fifty calibre guns, two in the fuselage and two in the wings, two 100 lb. type bombs, mounted under the wings, radio, navigating and oxygen equipment and deck carrier gear. Provision is available for armor and fuel tank protection.

" The fuselage is of monocoque construction with a forward portion of steel truss construction. The cockpit is covered by an enclosed canopy of plexiglas with a sliding portion for exit and entrance. There is a plexiglas window in the bottom for down vision.

" The wing is built up of a box beam with leading and trailing edge assemblies attached. The wing is entirely metal covered and may be easily removed from the fuselage for shipping purposes.

" The tail surfaces are cantilever type metal covered except the movable surfaces, which are fabric covered. The movable surfaces are mass balanced.

" The landing gear is constructed of built up aluminum alloy struts to which are attached steel elbows mounting integral oleo pneumatic strut and axle and hydraulic brakes. The landing gear is retractable. The tail wheel is of the swiveling type with 360° freedom which may be locked for take off and landing.

" The fuel tanks are integral with the wing beam and have a capacity of 160 gals. Additional provision for fuel may be made available in the wing leading edge and in the fuselage. The oil tank mounted in the forward upper portion of the fuselage has a capacity of 11 gals.

" The engine has a two speed mechanical type supercharger. The G100 type engine has an output of 1100 hp. for take off and five minutes operation at sea level and 775 hp. at 19,000 ft. in high blower including ram.

" The G200 type engine has an output of 1200 hp. for take off and five minutes at sea level and 900 hp. at 16,600 ft. in high blower including ram.

" Some performance data with Wright G200 Series Engine: Max. velocity at 16,600 ft., 345 m.p.h., Service ceiling, 34,000 ft. Rate of climb at sea level 4000 ft. per minute. Time to climb 15,000 ft., 5 minutes.

" Some performance data with Wright G100 Series Engine: Max. velocity at 19,000 ft., 330 m.p.h., Service ceiling, 34,000 ft. Rate of climb at sea level 3800 ft. per minute. Time to climb 15,000 ft., 5.1 minutes."

12–11. Biplanes. — The two-place biplane illustrated in Fig. 12–8 (Model BM-10A military primary trainer) is made by the Southern Aircraft Corporation, Garland, Dallas County, Texas. It is powered by a choice of engines — 225 hp. Lycoming R-680-B4C, Jacobs L-4 or Continental W-760-K, or 235 hp. Wright R-760-ET. It has welded steel tube fuselage. Wings, tail group and

FIG. 12–8. Biplane. (Southern Aircraft Corporation.)

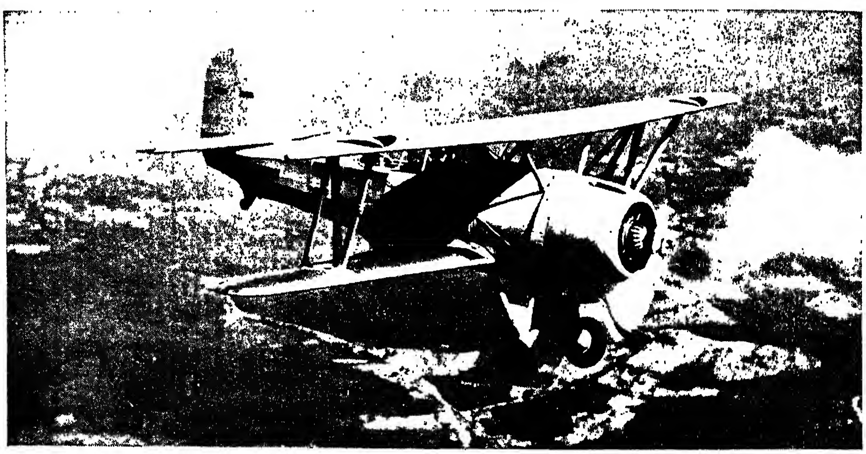


FIG. 12–9. Biplane, Scout Bomber. (Vought-Sikorsky Aircraft, Division of United Aircraft Corporation.)

control surfaces fabric over wood frames, or metal frames as desired. Equipped with hydraulic brakes and steerable tail wheel. Wing area, 304.5 sq. ft. Span, 34 ft. 1 in. gross weight, 2790 pounds. Maximum speed, 125 m.p.h. Cruising speed, 105 m.p.h. Service ceiling, 15,000 ft.

The SBU-1 Scout Bomber Biplane illustrated in Fig. 12–9 is made by Vought-Sikorsky Aircraft, Division of United Aircraft Corporation, Stratford, Connecticut. A line drawing of this plane is reproduced in Fig. 12–10.

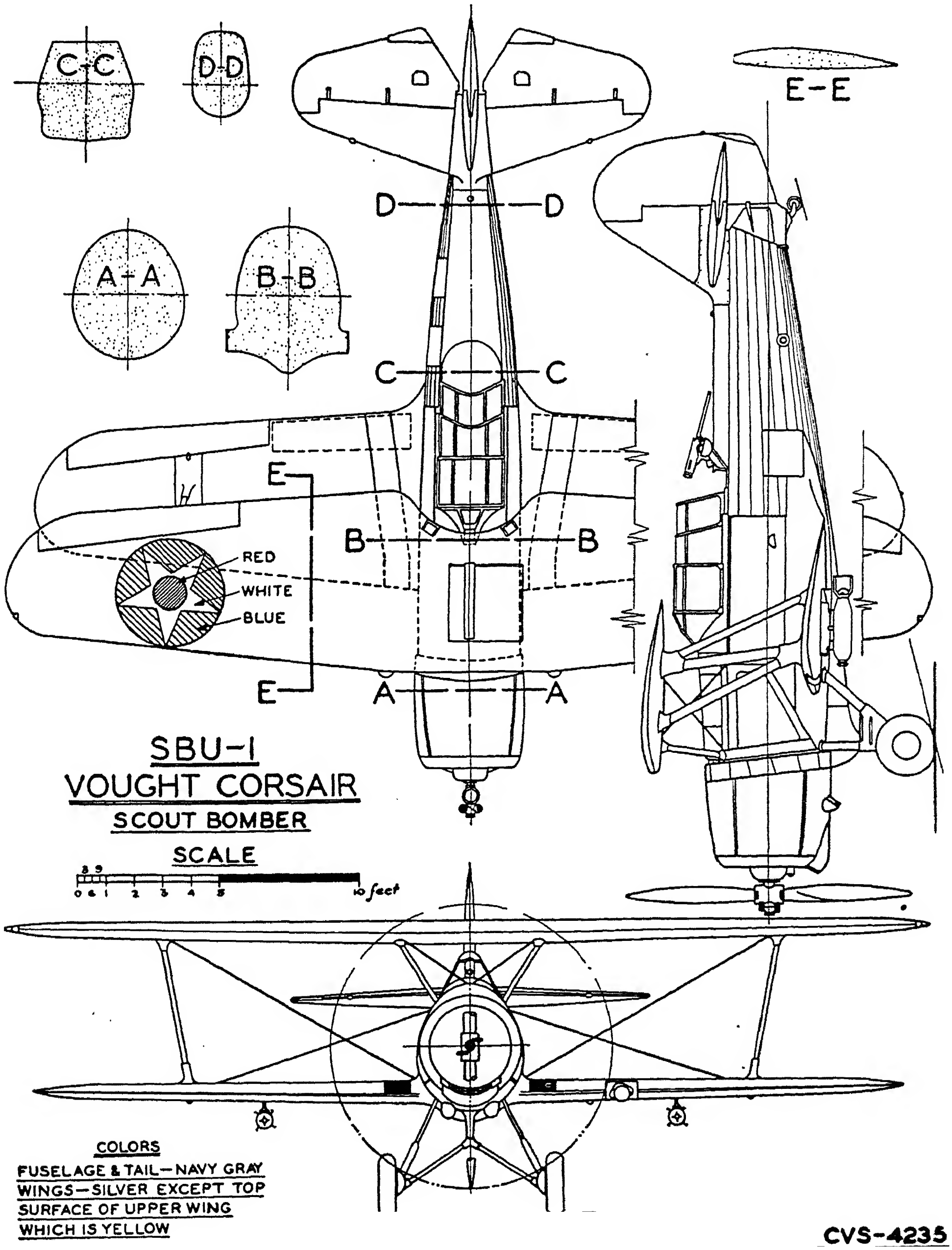


FIG. 12–10. Outline Drawing of Scout Bomber of Fig. 12–9. Prob. 14–3.

12–12. Airplane Construction. — Details of construction vary with the type of airplane and the materials used for the parts. There are certain general kinds of details, some of which are illustrated by the pictures and drawings in this book. Further studies should be made by examining different aircraft at every opportunity.

Spars (Figs. 12–11 and 12–13) are primarily beams which extend the full length of the wing. They are made of wood or metal — aluminum alloy and to some extent, stainless steel.

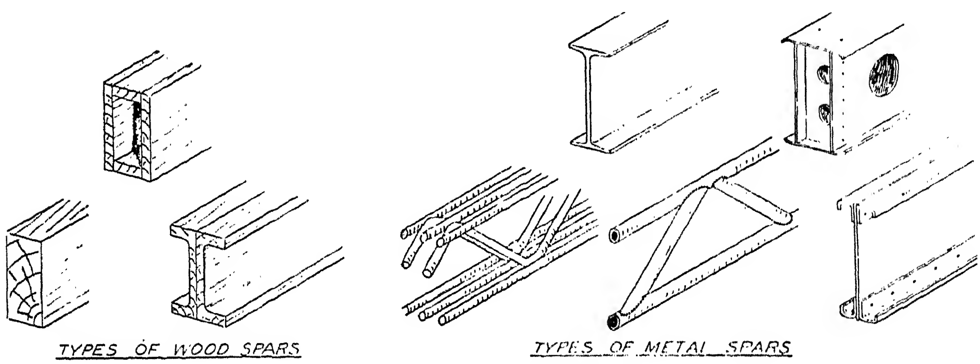


FIG. 12–11. Some Types of Spars.

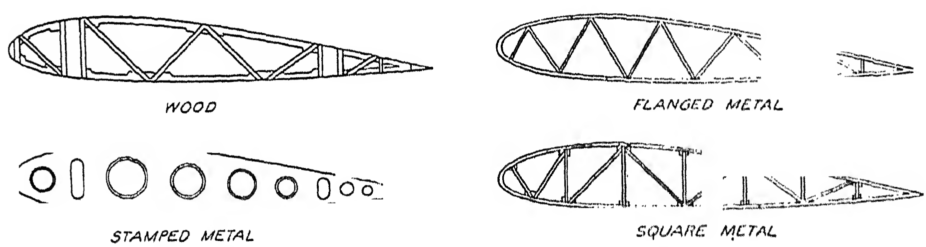


FIG. 12–12. Some Types of Ribs.

Ribs (Figs. 12–12 and 12–13) and compression struts are attached to the spars.

Struts are primarily compression members and include interplane struts to keep the wings apart and in correct position, drag struts (or compression ribs) which are the main compression members of the internal bracing system of a wing and parallel to the ribs, fuselage struts or braces between the longerons, tail or empennage struts, engine mount struts, landing gear struts and longerons. They are made of aluminum alloy or stainless steel tubing, streamline, round or extruded shapes, according to location and purpose.

Fittings include a great variety of small aircraft parts used to join structural members together. They are made of any of the aircraft materials, stainless steel or aluminum alloy sheet metal, aluminum alloy castings, bronze castings, forgings and a large number of standard and commercial fittings.

Fairings are coverings or parts used in the design of low-drag shapes as the streamline covering around the landing gear wheels and other places.

Cowlings are sheet-metal enclosures for the engine and are designed to direct the flow of air through and around the engine. They are generally installed so as to be easily detachable.

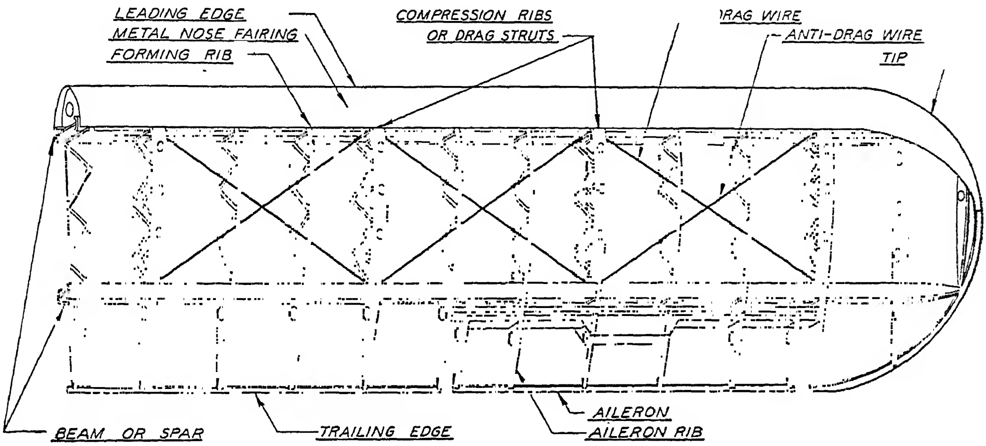


FIG. 12–13. Wing Construction. (Civil Aeronautics Administration.)

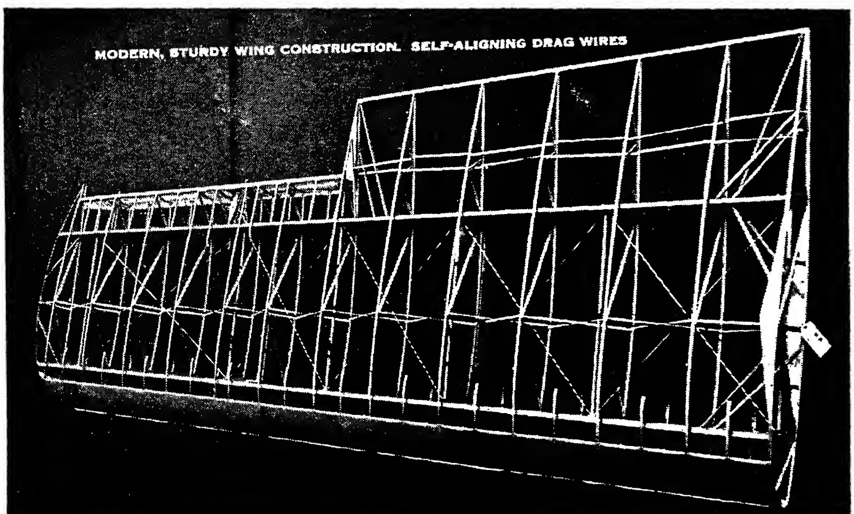


FIG. 12–14. Wing Construction. (Taylorcraft Aircraft Corporation.)

12–13. Wings. — The wing unit consists of a number of details in addition to the surfaces which provide lift, such as struts, wires and fittings and attached parts including the ailerons, slots and tabs. There are a number of types of wing construction, one of which is indicated in Fig. 12–13. The wing construction for a Taylorcraft airplane is shown in Fig. 12–14. A wing-tip skeleton of a Brewster

airplane is shown in Fig. 12–15, an aileron skeleton in Fig. 12–16 and part of an aileron drawing in Fig. 12–17.

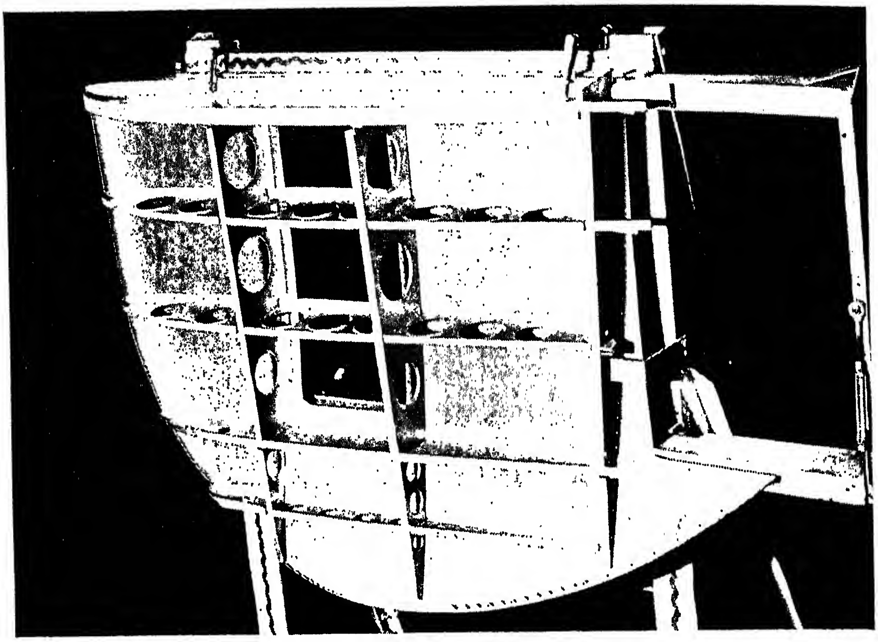


Fig. 12–15. Wing Tip Skeleton — One Side Covered. (Brewster Aeronautical Corporation.)

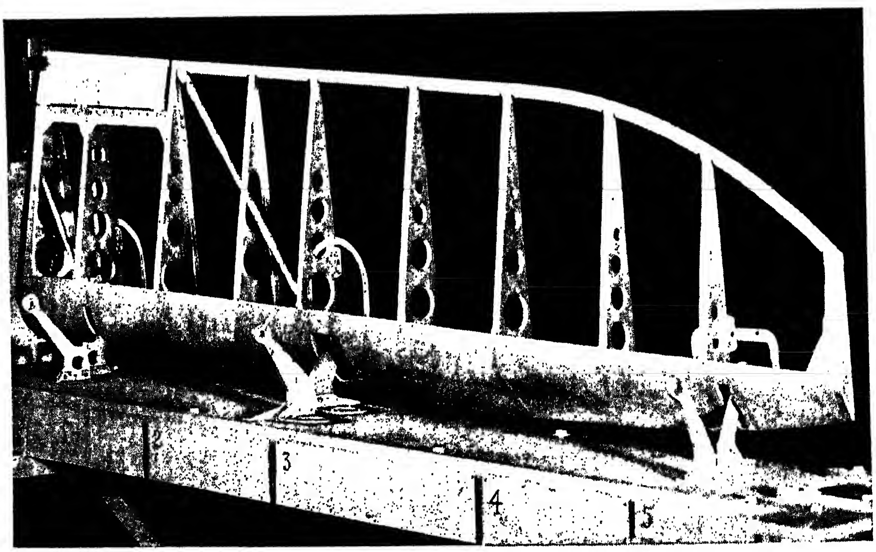


Fig. 12–16. Aileron Skeleton — Left Hand (With Tab) (Brewster Aeronautical Corporation).

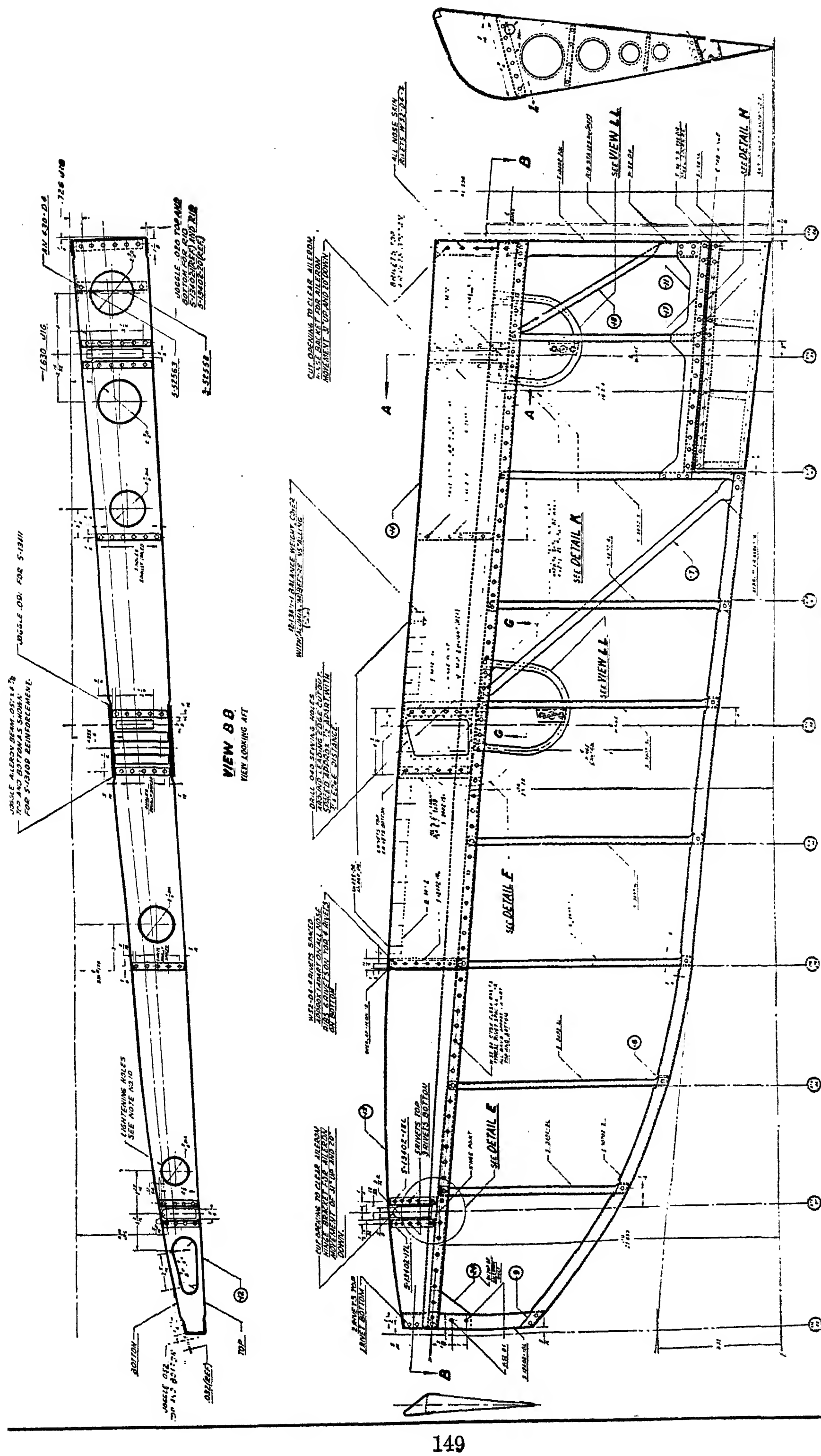


FIG. 12-17. Part of a Drawing of an Aileron Assembly. (Brewster Aeronautical Corporation.)

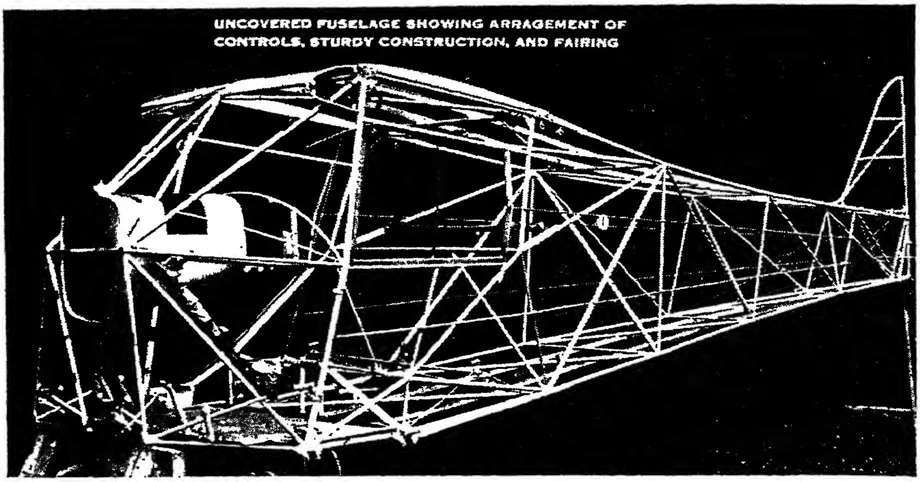


FIG. 12–18. Truss-Type Fuselage. (Taylorcraft Aircraft Corporation.)

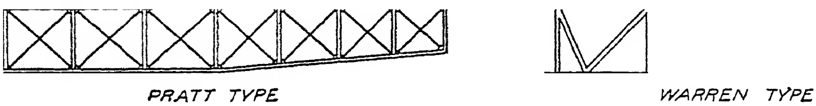


FIG. 12–19. Fuselage Trusses. (Civil Aeronautics Administration.)

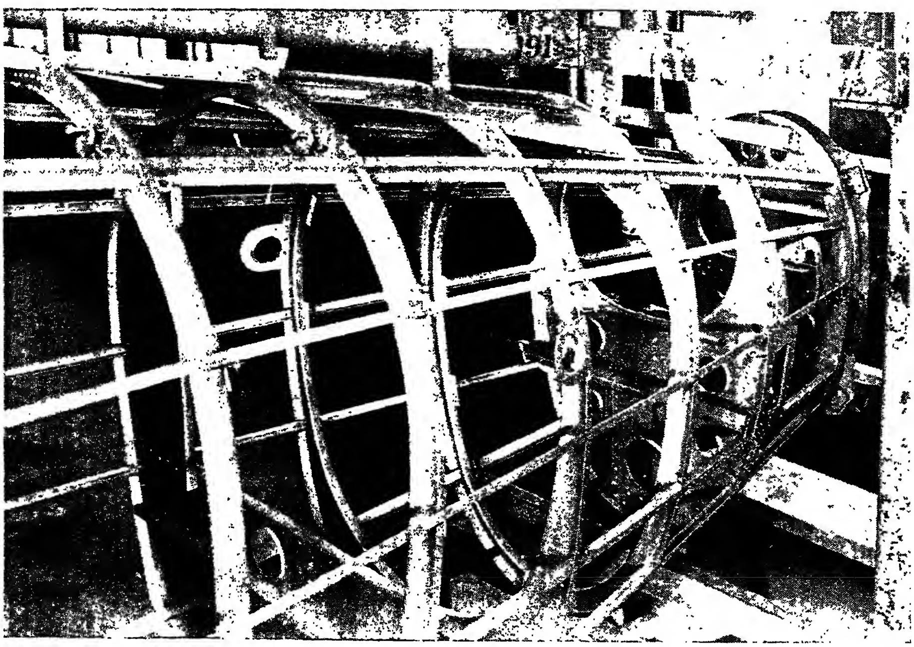


FIG. 12–20. Monocoque Skeleton — Aft end. (Brewster Aeronautical Corporation.)

12–14. Fuselage. — The fuselage construction is classified as truss type, semi-monocoque type and monocoque type. In all of these there must be a suitable contour to offer low air resistance and good vision while providing space for the pilot, crew and passengers, the engine, and all necessary equipment and operating facilities. There must be sufficient strength for the forces to be met and provision for the attachment of the wings, empennage and landing gear. A truss type fuselage is illustrated in Fig. 12–18 and two types of fuselage trusses in Fig. 12–19. A portion of a monocoque skeleton is shown is Fig. 12–20 and a drawing of one section or frame is shown in Fig. 12–21.

12–15. Empennage. — This is also called the tail group and includes the elevator, stabilizer, rudder and fin, together with the necessary bracing wires and struts (Fig. 12–22). A fin assembly is shown in Fig. 12–23 and a drawing in Fig. 12–24.

12–16. Landing Gear. — This very important unit or understructure supports the weight of the airplane and is designed to absorb or reduce the shock of landing. Wheel-type gear is used for landing on hard surfaces, ski-type on snow, and float type on water. There are so many types of landing gear and shock absorbers that no attempt will be made to illustrate the details.

A plain landing gear with Oleo shock absorber is illustrated in Fig. 12–25. There are many kinds of retractable landing gear with mechanical or hydraulic operation to fold the wheels into the airplane. A retractable landing gear type is shown in Fig. 12–26.

12–17. Springs. — Some springs are illustrated in Fig. 12–27 and the necessary dimensions and information are indicated on Fig. 12–28. In general springs are designed by calculation and experiment and drawn to meet complete specifications including size of wire, material, diameter, pitch, number of coils, length, style of ends, methods of fastening, etc.

12–18. Gears. — The general terms for spur gears are illustrated in Fig. 12–29. The *pitch circle* has a diameter equal to the diameter of the friction wheel which the gear replaces. The *circular pitch* is the distance from a point on one tooth to the corresponding point on the next tooth, measured along the pitch circle. The *diametral pitch* is the number of teeth per inch of diameter; it is the ratio of the number of teeth to the pitch diameter. For the construction of the involute of a circle see Fig. 3–41. Some gear drawings are suggested in Fig. 12–30.

12–19. " There are in use today several forms of gear teeth. Three forms which have become more or less standardized are the 14½-degree full length tooth involute form, the 20-degree full-length tooth involute form, and the 20-degree stub-tooth form. The so-called 14½-degree involute tooth form has a pressure angle, or angle of obliquity, of 14½ degrees; hence the rack meshing with gears cut according to this system has teeth with straight sides (since the base circle would have an infinite radius) inclined 14½ degrees from the vertical or an included angle of 29 degrees.

" The 20-degree full-length tooth form has the same tooth length as the so-called 14½-degree form, but instead of a 14½-degree pressure angle, it has an angle of 20 degrees. The stub-tooth form is a modification of both of these two systems; the original was developed by The Fellows

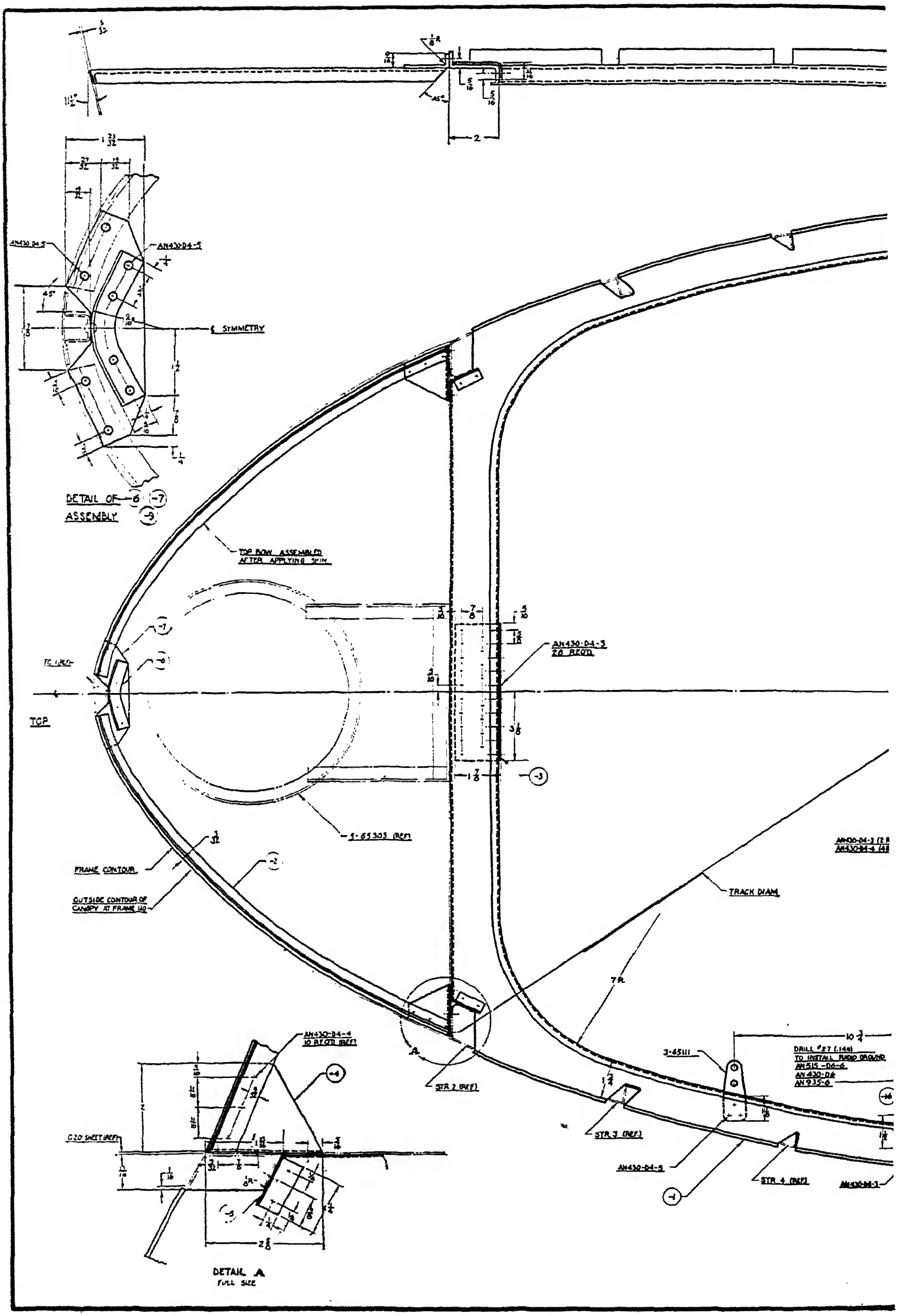
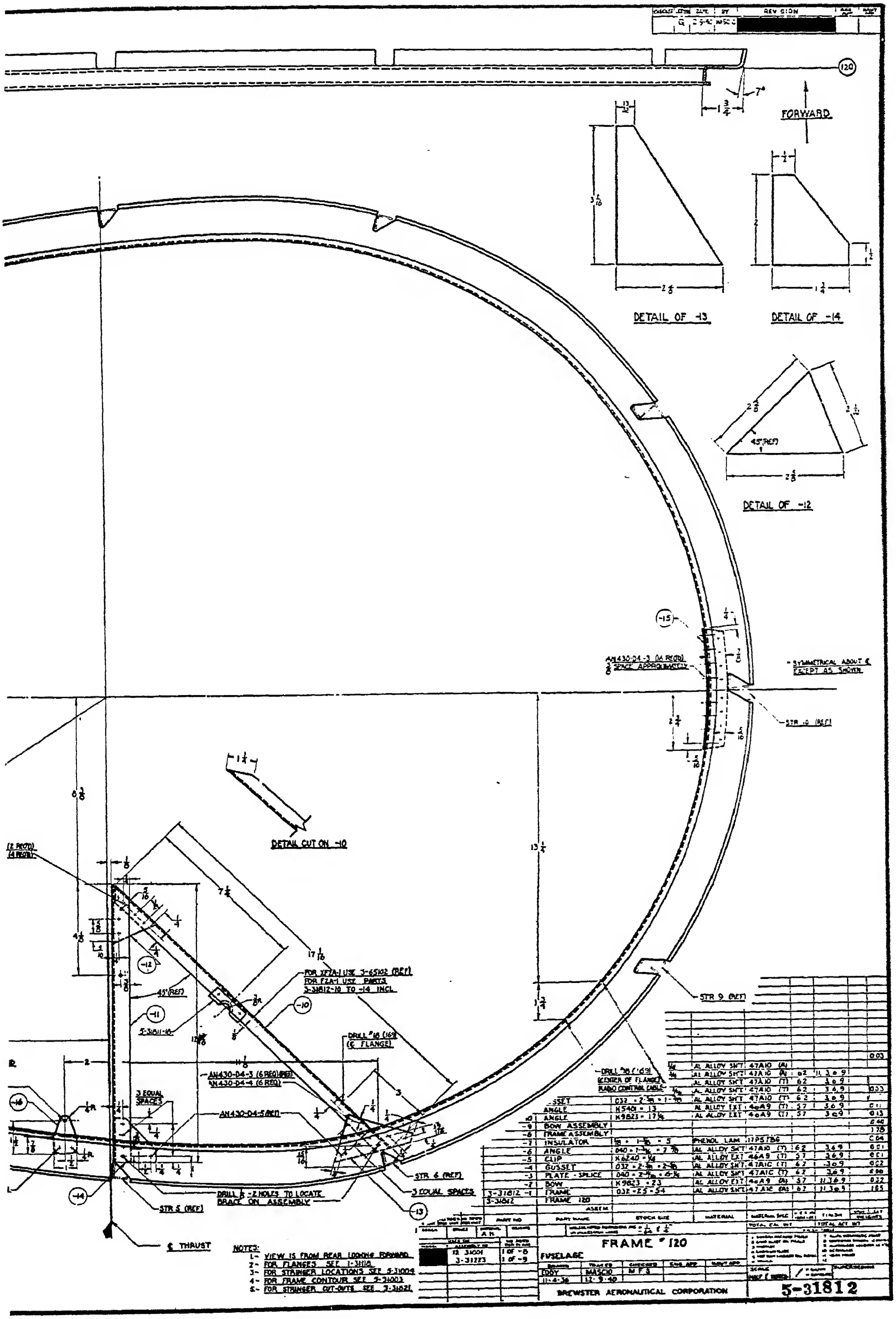


Fig. 12–21. Frame — Monocoque Fusilage.



(Brewster Aeronautical Corporation.)

Gear Shaper Company in 1899. . . . The stub tooth has, of course, greater strength than either the 14½-degree or 20-degree full-length tooth forms and until the adoption of present alloy steels this factor of greater strength was of considerable importance. The so-called Fellows stub-tooth system is based on two diametral pitches; the first, say 6, being used as a basis for obtaining the dimensions for the thickness of the tooth, the number of teeth and the pitch diameter; while the other, say 8, is used for obtaining the dimensions for the addendum and dedendum. A stub tooth therefore denoted as 6/8 pitch would have a length of tooth equal to that of an 8-pitch gear and a circular pitch equal to that of a 6-pitch gear. A 21-tooth gear of this pitch would have a pitch diameter of 3½ inches and an outside diameter of 3¾ inches.

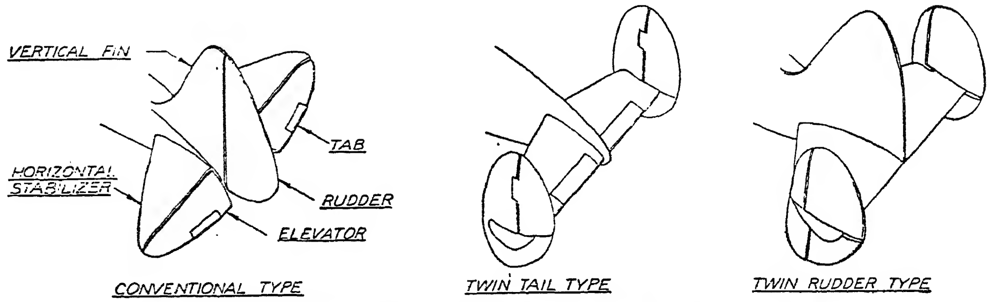


Fig. 12–22. Empenage Types. (Civil Aeronautics Administration.)

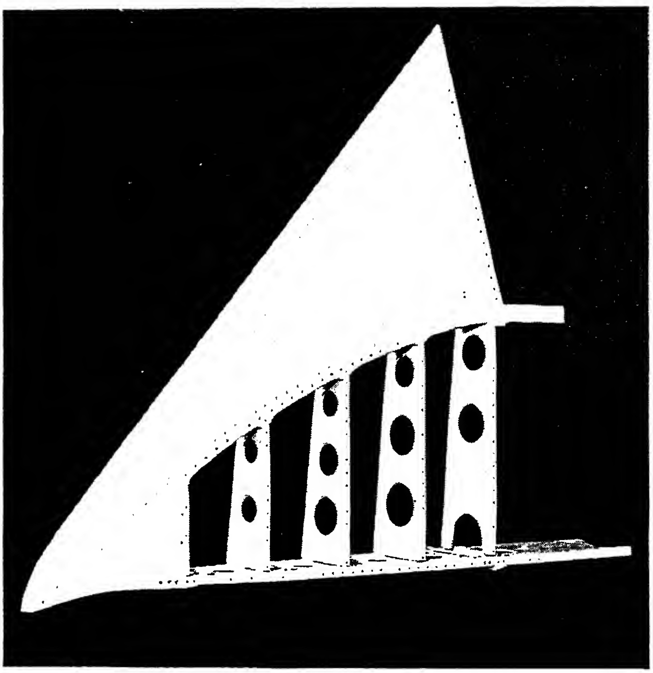


Fig. 12–23. Fin Assembly — Partially Covered. (Brewster Aeronautical Corporation.)

" Recently the American Gear Manufacturers Association has adopted a so-called stub-tooth system in which the addendum is a constant proportion throughout the entire range of pitches. In the case of the Fellows stub-tooth system the addendum on the 45 pitch and the 6/8 pitch are not proportional. On the A.G.M.A. standardthe addendum is 8/10 of an inch based on 1 diametral pitch for all range of pitches. The pressure angle, however, is the same — 20 degrees."[4]

[4] *The Involute Gear*, The Fellows Gear Shaper Co., Springfield, Vermont.

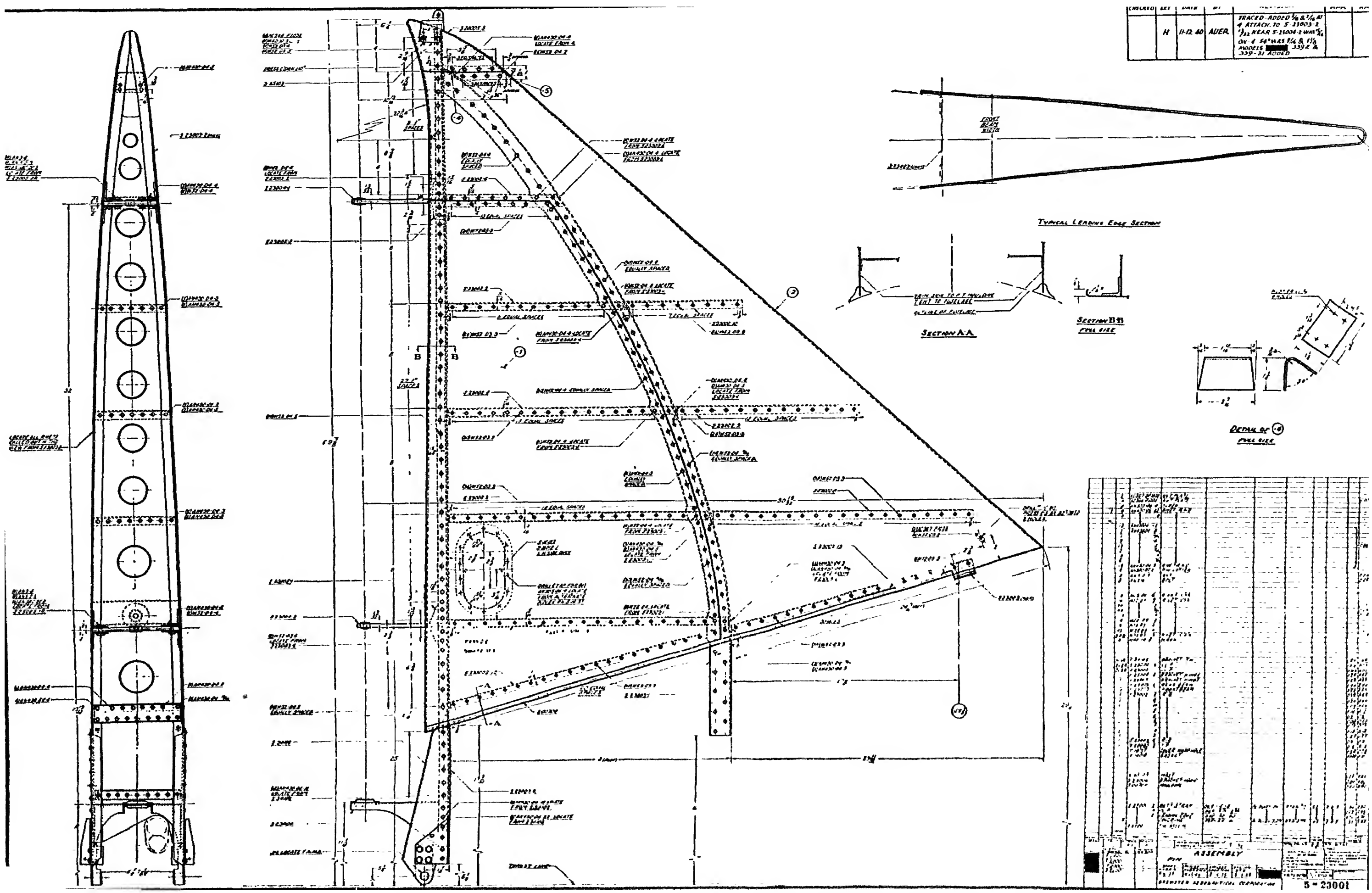


FIG. 12–24. Fin Assembly. (Brewster Aeronautical Corporation.)

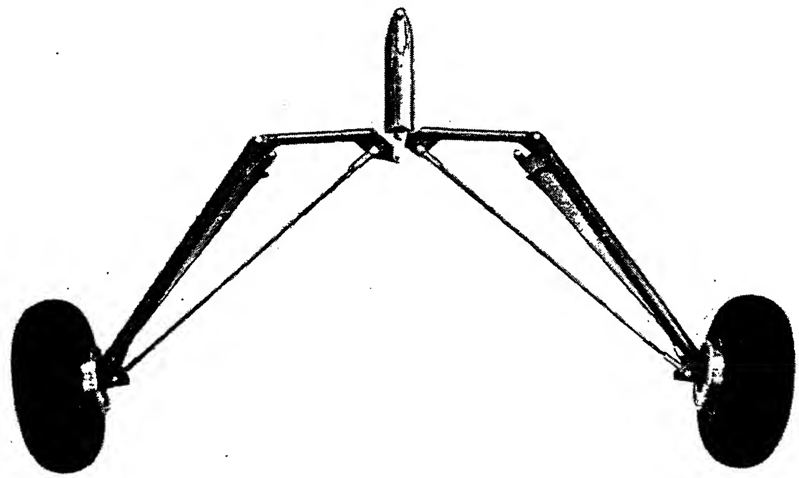


FIG. 12–25. Landing Gear. (Interstate Aircraft and Engineering Corporation.)

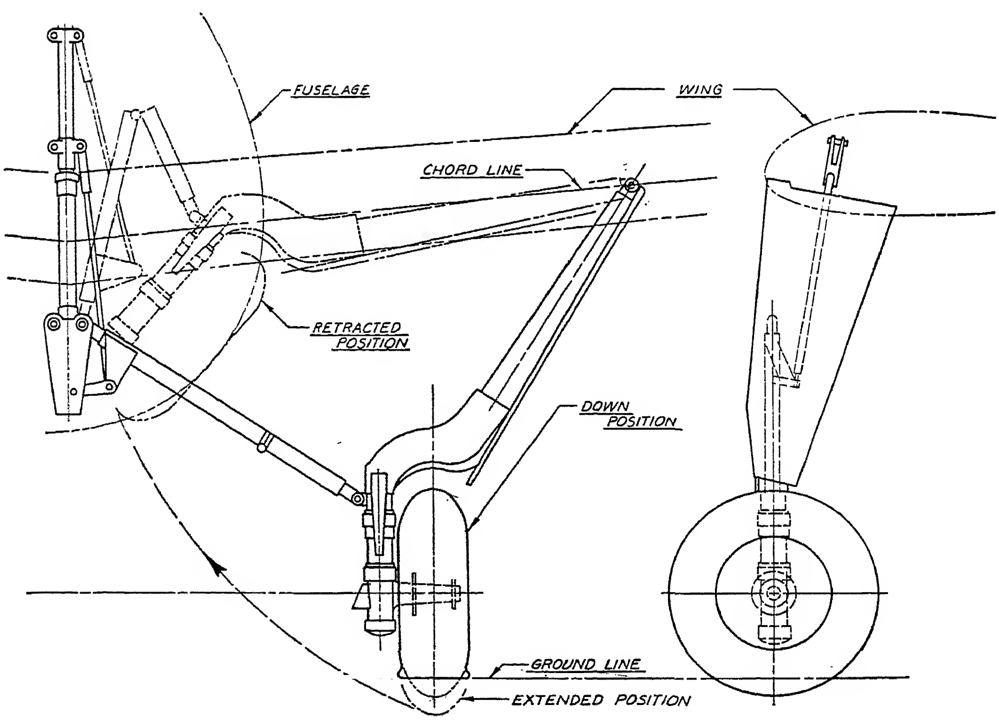


FIG. 12–26. Retractable Landing Gear.

Proportions for Spur Gears
(*Condensed from American Standards*)

System	14½ Deg. Composite 14½ Deg. and 20 Deg. Full Depth Involute		20 Deg. Stub Involute[5]	
	In Terms of Diametrical Pitch[1] (Inches)	In Terms of Circular Pitch[1] (Inches)	In Terms of Diametral Pitch[1] (Inches)	In Terms of Circular Pitch[1] (Inches)
1. Addendum	$\frac{1}{DP}$	$0.3183 \times CP$	$\frac{0.8}{DP}$	$0.2546 \times CP$
2. Minimum Dedendum[2]	$\frac{1.157}{DP}$	$0.3683 \times CP$	$\frac{1}{DP}$	$0.3183 \times CP$
3. Working Depth	$\frac{2}{DP}$	$0.6366 \times CP$	$\frac{1.6}{DP}$	$0.5092 \times CP$
4. Minimum Total Depth[2]	$\frac{2.157}{DP}$	$0.6866 \times CP$	$\frac{1.8}{DP}$	$0.5729 \times CP$
5. Pitch Diameter	$\frac{N}{DP}$	$0.3183 \times N \times CP$	$\frac{N}{DP}$	$0.3183 \times N \times CP$
6. Outside Diameter	$\frac{N + 2}{DP}$	$0.3183 \times (N + 2) \times CP$	$\frac{N + 1.6}{DP}$	PD + (2 Addendums)
7. Basic Tooth Thickness on Pitch Line	$\frac{1.5708}{DP}$	$0.5 \times CP$	$\frac{1.5708}{DP}$	$0.5 \times CP$
8. Minimum Clearance[2,3]	$\frac{0.157}{DP}$	$0.05 \times CP$		
9. Minimum Clearance[2,4]			$\frac{0.2}{DP}$	$0.0637 \times CP$
10. Radius of Fillet[6]				

N = Number of Teeth. DP = Diametral Pitch. CP = Circular Pitch.

[1] Note: The term Diametral Pitch is used up to 1 DP inclusive and the term Circular Pitch is used for 3 inches CP and over.

[2] Note: A suitable working tolerance should be considered in connection with all minimum recommendations.

[3] Note: Minimum clearance refers to the clearance between the top of the gear tooth, and the bottom of the mating gear space, and is specified as "minimum" so as to allow for necessary cutter clearance for all methods of producing gears. At the present time this value cannot be standardized.

[4] Note: A minimum root clearance of 0.2 inch/Diametral Pitch is recommended for new cutters and gears. There is correct tooth action, however, between gears cut to this standard system and those cut to the Nuttall system, the only dimension affected being the clearance. Where the proposed gear tooth meshes with a Nuttall gear space there is a clearance of 0.1425 inch/Diametral Pitch, and where the Nuttall tooth runs with the proposed gear space there is a clearance of 0.2146 inch/Diametral Pitch.

[5] Note: These proportions are identical with those of the A.G.M.A. recommended practice for Herringbone Gears.

[6] Radius of Fillet: For 14½ deg. Composite and 14½ deg. Full Depth Involute = 1⅓ × Clearance; for 20 deg. Full Depth Involute = 1½ × Clearance.

12–20. Castings are made by filling a space or cavity of the desired shape with hot metal. When the cavity is molded by a wooden pattern in sand, a sand casting is obtained. Rather complicated shapes can be produced by casting and this method often provides an easy and desirable method of manufacture. Due

to the character of the surface extra material must be allowed for machining. Shrinkage strains must be provided against by using large fillets, arranging for uniform cooling of the various parts, avoiding slender projecting parts, avoiding sudden changes in the sizes of adjacent sections, etc. A drawing of a casting is

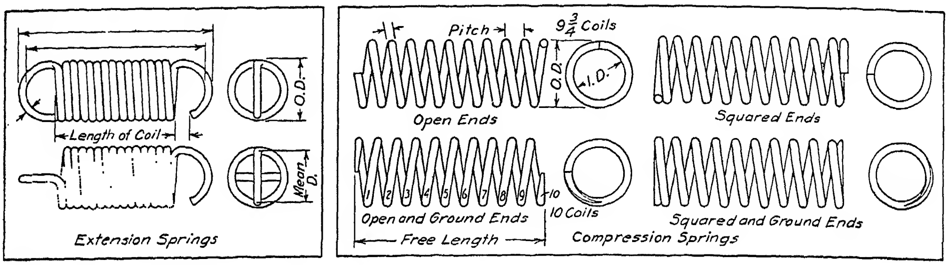


FIG. 12–27. Springs.

shown in Fig. 9–4. The use of castings is restricted to certain purposes for which this method and the metals used are adapted. The uniformity and strength of welded or forged parts cannot be attained in castings. Aircraft parts may be cast in aluminum, bronze, steel, or any one of a number of alloys. Minimum

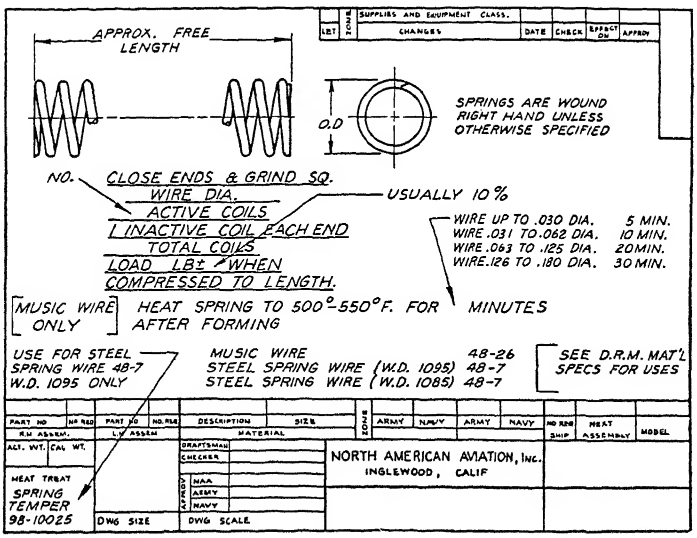


FIG. 12–28. Spring Drawing.

thickness of webs varies from ⅛ in. for aluminum and bronze to ¼ in. for steel, with minimum fillets of the same radii.

12–21. Die castings are made by forcing molten or semi-molten metal into metallic molds under pressure greater than atmospheric. Smooth surfaces and rather accurate dimensions can be obtained. Metals used include zinc alloys,

aluminum alloys and magnesium alloys, with this last finding its greatest use in aircraft manufacture. Section thicknesses of .090 to .100 inches may be used on large aluminum die castings, and on castings less than 6 inches in length thicknesses may be from .060 to .075 inches.

12–22. Forgings. — Hand forgings of aluminum alloy are used when a few parts are to be made as for experimental and development work. The material is heated to a plastic or semi-molten state and formed or shaped by hand, using special tools such as hammers, sets, etc.

A drop-forging is the basic cleaned, trimmed and sized metal article initially formed by placing and working hot metal in plastic (or partly solid) state between reciprocating die impressions, forms or cavities in closed dies.

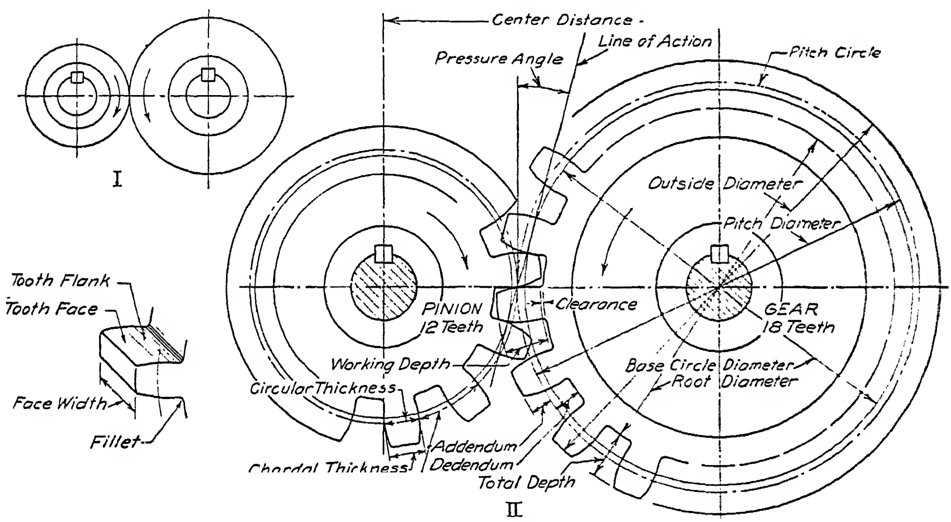


FIG. 12–29. Spur Gear Terms.

12–23. Reproduction of Drawings. — The usual method of making copies of drawings is by direct contact printing. The drawing on tracing paper or cloth is placed with the drawing side against glass. Paper with a " light sensitive " coating is held in contact with the drawing while light is supplied through the glass. If blue-print paper is used it is removed and washed in water. The result is a white line drawing on a blue ground. Other papers may be used to obtain prints with blue, black, brown red, etc., lines on a light ground. Development may be wet (using the proper solutions) or dry (using vapors) according to the particular paper used. Electric printing machines with equipment to give finished prints are used. Enlarged, reduced or same size copies (photostats) are made with the Photostat (a specially designed camera).

Other methods of reproduction include the offset printing process, the hectograph and the mimeograph.

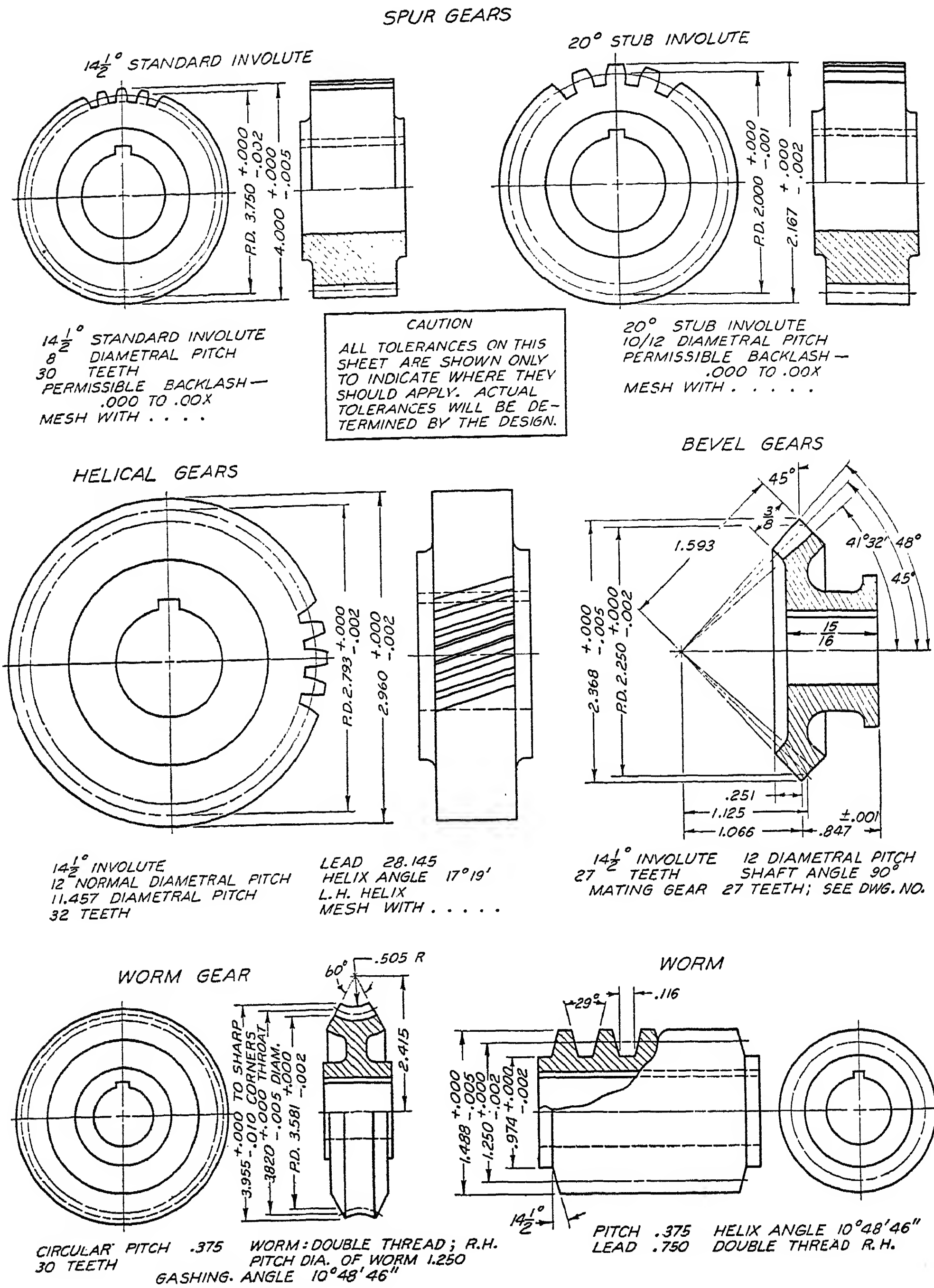


Fig. 12–30. Gear Drawings. (Courtesy of the Curtiss Aeroplane Division, Curtiss-Wright Corporation, Buffalo, New York.)

12-24. PROBLEMS. — A selection from the following problems should be worked out as complete drawings. Study the problem, consider the choice and treatment of views and the scale. Then select the proper size sheet and when the views are complete add the necessary dimensions and notes. All of the preceding chapters are preparation for these problems.

Certain conditions have made it desirable or necessary to modify or omit some details of design and to omit or change some dimensions. Such information as may be needed to complete any drawings, including indication of finished surfaces, etc., is to be worked out on the drawing in consultation with the instructor. Reference should also be made to Chapter XVII.

Prob. 12-1. Fig. 12-31. — Make a detail drawing of the OIL TANK FILLER NECK. Cast aluminum alloy (Alcoa 108). Full size. Change the view given to a section and draw the other views where indicated. (Southern Aircraft Corporation.)

Prob. 12-2. Fig. 12-32. — Make a working drawing of the UNIVERSAL BLOCK, main landing gear, lateral strut. Aluminum alloy 17ST, bar-stock. Steel bushings. Supply missing dimensions. Add note: " Anodize block before pressing in bushings." Full size. Consider choice and treatment of views. (Southern Aircraft Corporation.)

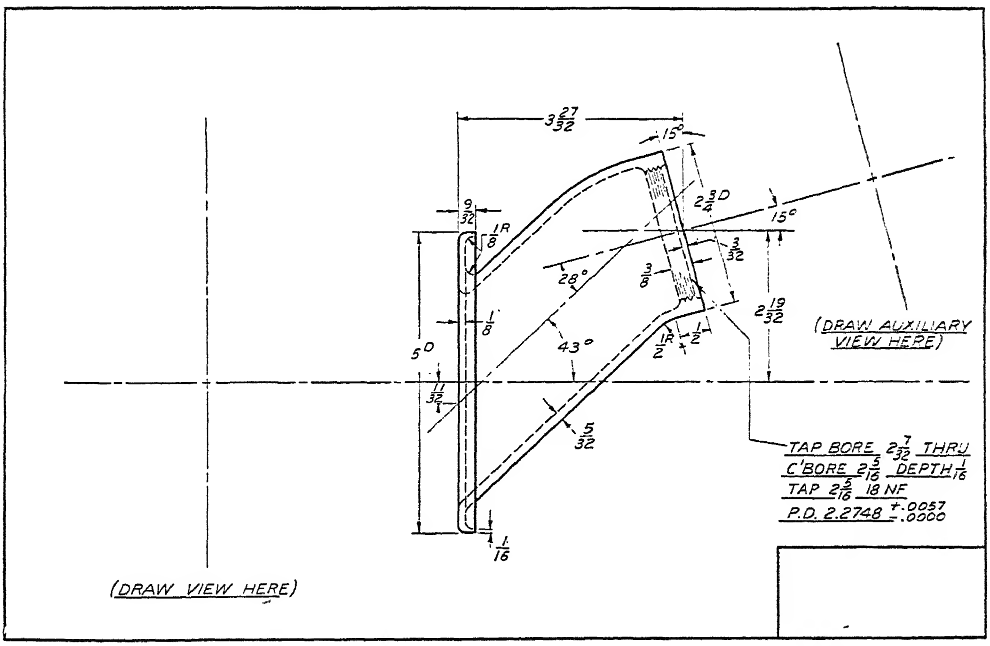


FIG. 12-31. Oil Tank Filler Neck. Prob. 12-1.

Prob. 12-3. Fig. 12-33. — Make a drawing of the LUG ASSEMBLY, Fuselage Front, Station 61 & 88. Material: Molybdenum steel (X4130). Also details of the center plate and L.H. side plate, with dimensions, etc. Call for R.H. side plate. Parts are to be welded together. Steel tube to extend equally on each side. (Southern Aircraft Corporation.)

Prob. 12-4. Fig. 12-34. — Make a RIB SPACING LAYOUT as shown. Scale: ¾ equals 1 ft. (Piper Aircraft Corporation.)

Prob. 12-5. Fig. 12-35.—Make a three-view drawing of the FITTINGS, Engine Ribs, Center Wing. Show typical sections. (The Glenn L. Martin Company.)

Prob. 12-6. Fig. 12-36.—Make a drawing of the ROD ASSEMBLY, Elev. Trim Tab Cont. Dimensions not shown are to be obtained from the graphic scale. (Boeing Aircraft Company.)

Prob. 12-7. Fig. 12-37.—Make a detail drawing of the ANGLE, Hydro-Stab. Fr. Spar. Aluminum forging. Full size. Show necessary views and part views. Supply additional necessary dimensions. (Boeing Aircraft Company.)

Prob. 12-8. Fig. 12-38.—Make a detail drawing of the STARTER ADAPTER BEARING RETAINER. Aluminum alloy (195-T4). The retainer is symmetrical. One-half is shown in the picture. Draw complete. Full size. (Kinner Airplane & Motor Corporation.)

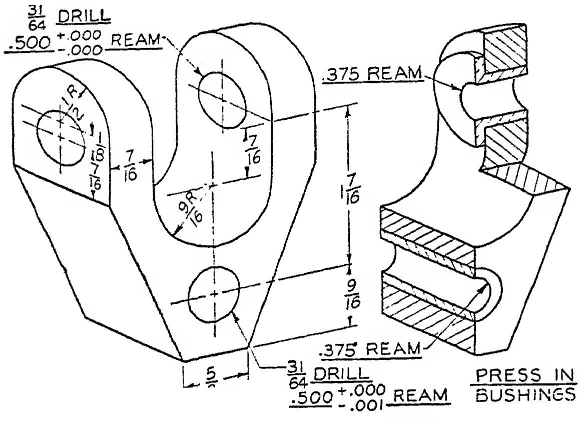


Fig. 12-32. Universal Block. Prob. 12-2.

Prob. 12-9. Fig. 12-39.—Make a detail drawing of the STEERING SLEEVE, oleo strut, nose wheel. Aluminum alloy (195-T6). Steel bushing to be inserted, .5000 diameter hole, and ream bushing $\frac{.375}{.378}$ Full size. Consider choice and treatment of views very carefully in connection with the layout shown. (Engineering and Research Corporation.)

Prob. 12-10. Fig. 12-40.—Make a detail drawing of the WING DRAG STRUT FOOT AND TIE ROD FITTING. 1/16″ No. 1025 Steel sheet. Draw two times full size. (Taylor Aircraft Company.)

Prob. 12-11. Fig. 12-41.—Make a drawing of the WING DRAG STRUTS. Tubes are No. 1025 steel. Layout is for 11 × 17 sheet. Foot E-2-1008 is shown in Fig. 12-40. Foot to be welded on one end of #1 drag strut. Foot to be welded on both ends of struts, #2, #3 and #4. (Taylor Aircraft Company.)

Prob. 12-12. Fig. 12-42.—Make a detail drawing of the TUBE BRACKET, RUDDER AND ELEVATOR HINGE. Cast aluminum alloy (Alcoa 195). All fillets 3/32R. Full size. (Southern Aircraft Corporation.)

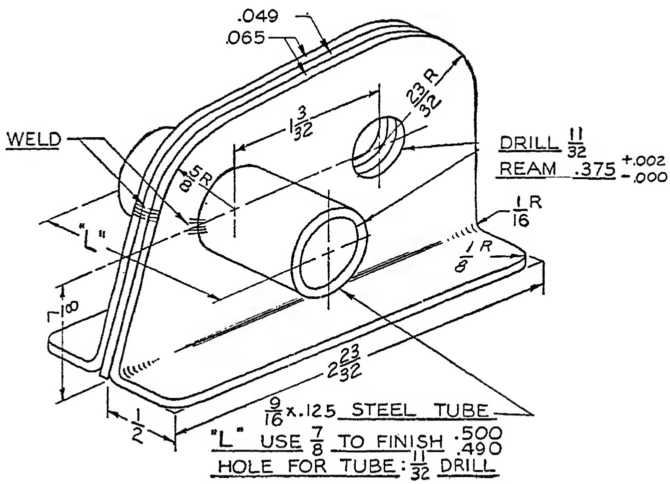


Fig. 12-33. Lug Assembly. Prob. 12-3.

Prob. 12-13. Fig. 12-43.—Make a drawing of the BRACKET, Tail Light Mounting. Draw two times full size. Bracket: Chromium Molybdenum Steel (4130). Rivets: 3/32 Dia. Countersunk Head, aluminum alloy (A-17-St.). Elastic Stop Nuts to be shown in place at (C). For stop nuts, see Chapter X. (Engineering and Research Corporation.)

Prob. 12–14. Fig. 12–44.—Make a detail drawing of the OIL TANK MOUNTING BRACKET. Cast magnesium alloy (Dow Metal H). Heat treated. Full size. Consider choice and treatment of views. (Southern Aircraft Corporation.)

Prob. 12–15. Fig. 12–45.—Make a detail drawing of the HEAD, main landing gear, cylinder. Material: steel bar (4130). Full size. Add note: "Break sharp corners." (Engineering and Research Corporation.)

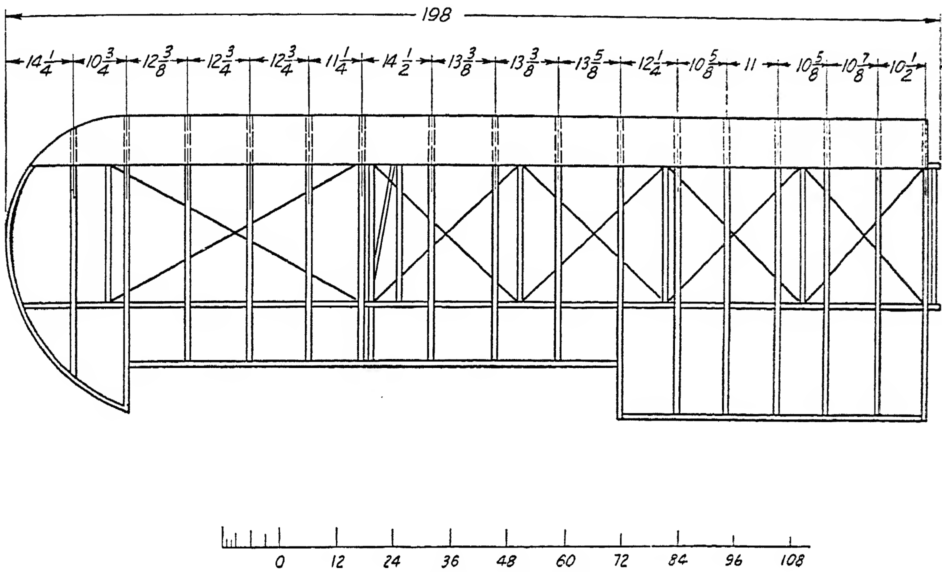


FIG. 12–34. Rib Spacing Layout. Prob. 12–4.

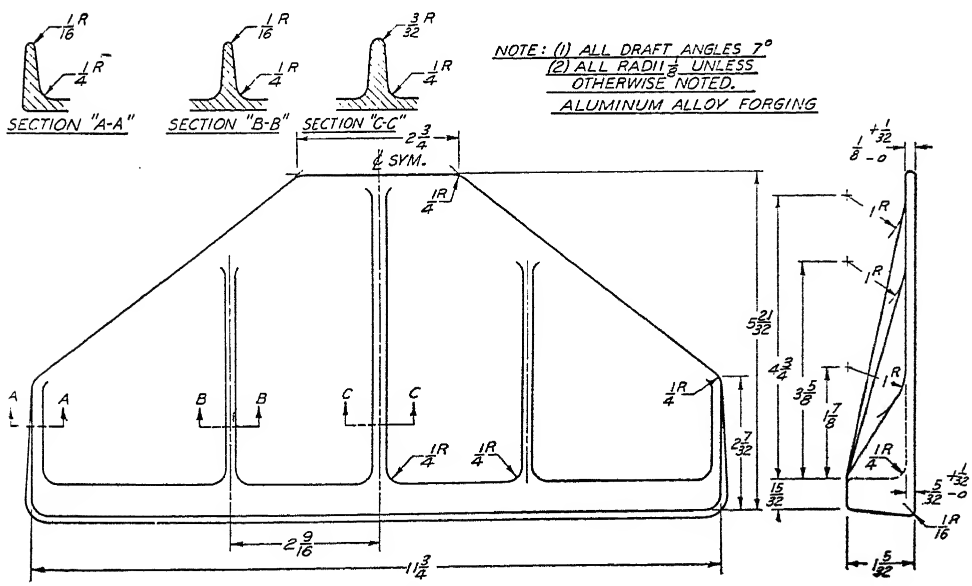


FIG. 12–35. Fitting. Prob. 12–5.

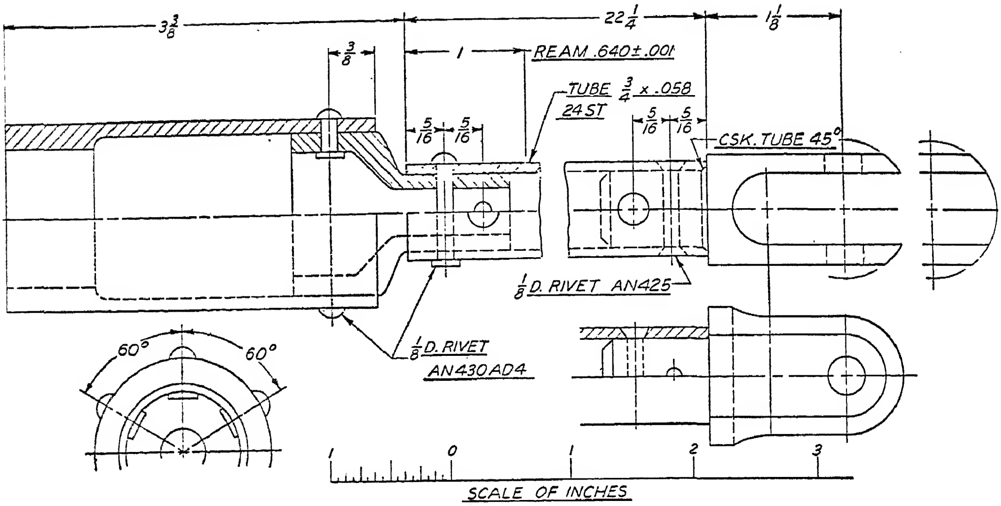


FIG. 12-36. Rod Assembly. Prob. 12-6.

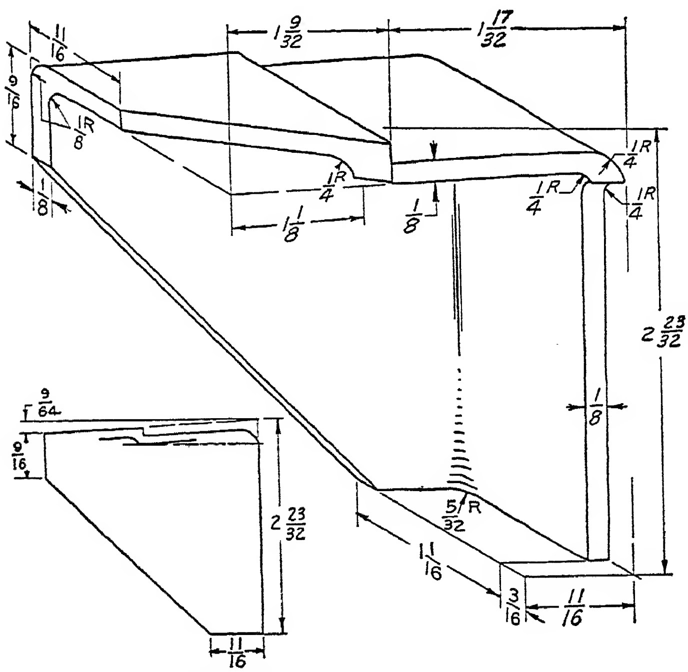


FIG. 12-37. Angle. Prob. 12-7.

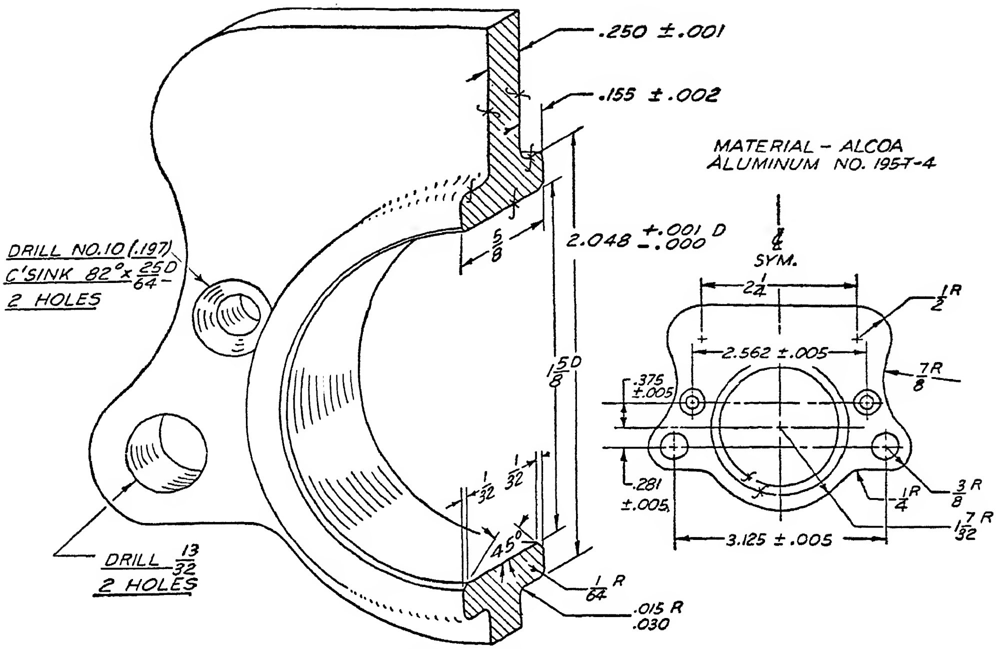


Fig. 12–38. Starter Adapter Bearing Retainer. Prob. 12–8.

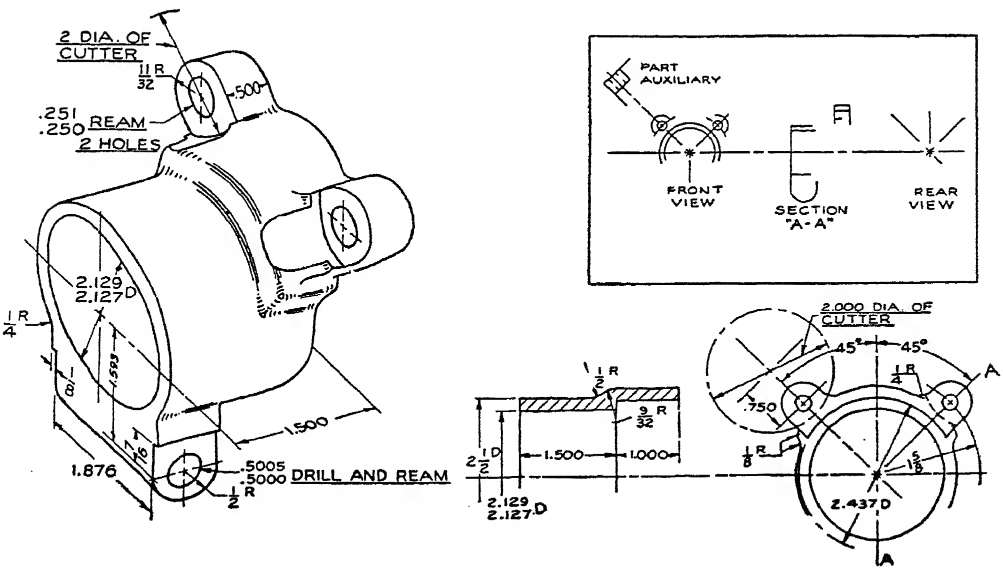


Fig. 12–39. Steering Sleeve. Prob. 12–9.

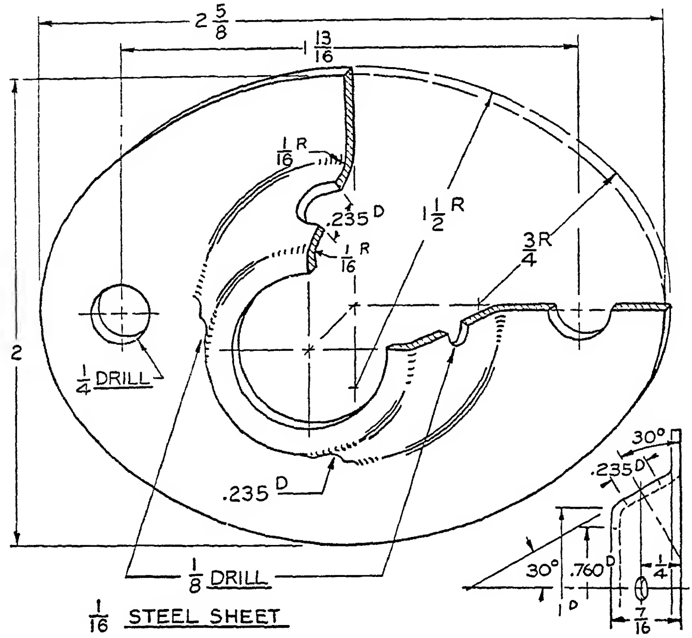


Fig. 12–40. Fitting. Prob. 12–10.

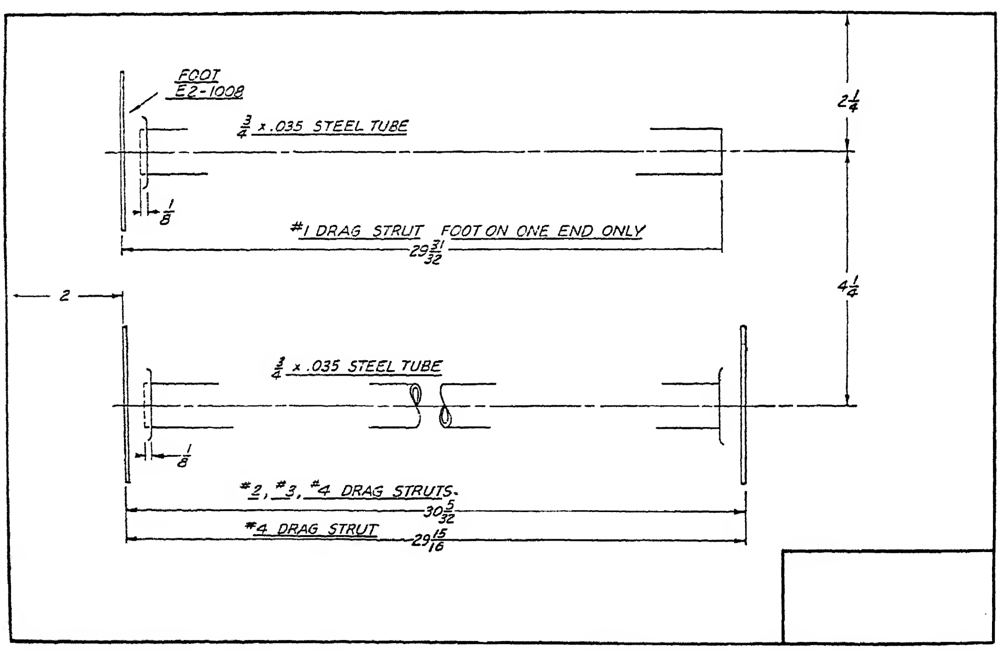


Fig. 12–41. Wing Drag Struts. Prob. 12–11.

Prob. 12–16. Fig. 12–46. — Make a detail drawing of the BRACKET, stabilizer, rudder controls. Casting, aluminum alloy (220–T4). Full size. (Engineering and Research Corporation.)

Prob. 12–17. Fig. 12–47. — Make a drawing of the GEAR, Upper, Camshaft Drive Shaft as indicated.

Prob. 12–18. Fig. 12–48. — Make a drawing of the GEAR, Lower Camshaft Drive Shaft as indicated.

Prob. 12–19. Fig. 12–49. — Make a drawing of the GEAR, Upper, Vertical Drive Shaft as indicated.

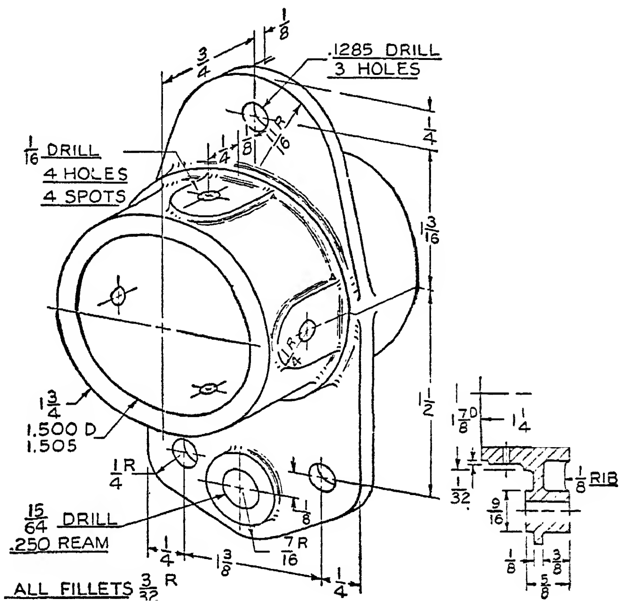


Fig. 12–42. Tube Bracket. Prob. 12–12.

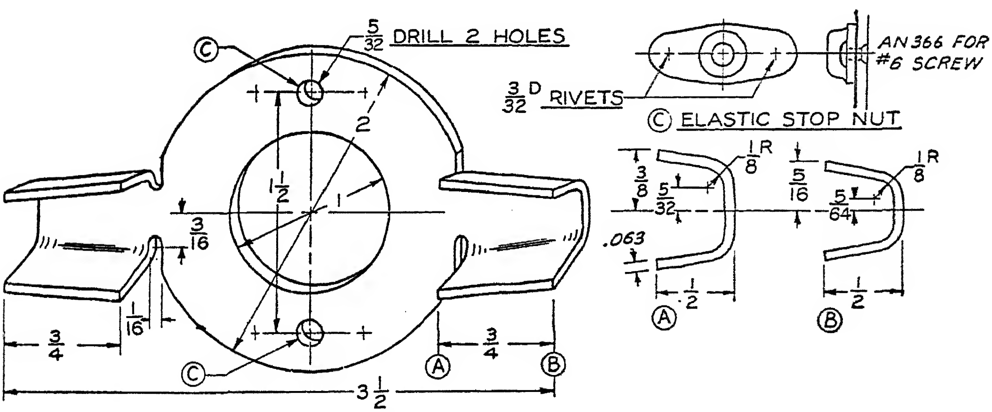


Fig. 12–43. Bracket. Prob. 12–13.

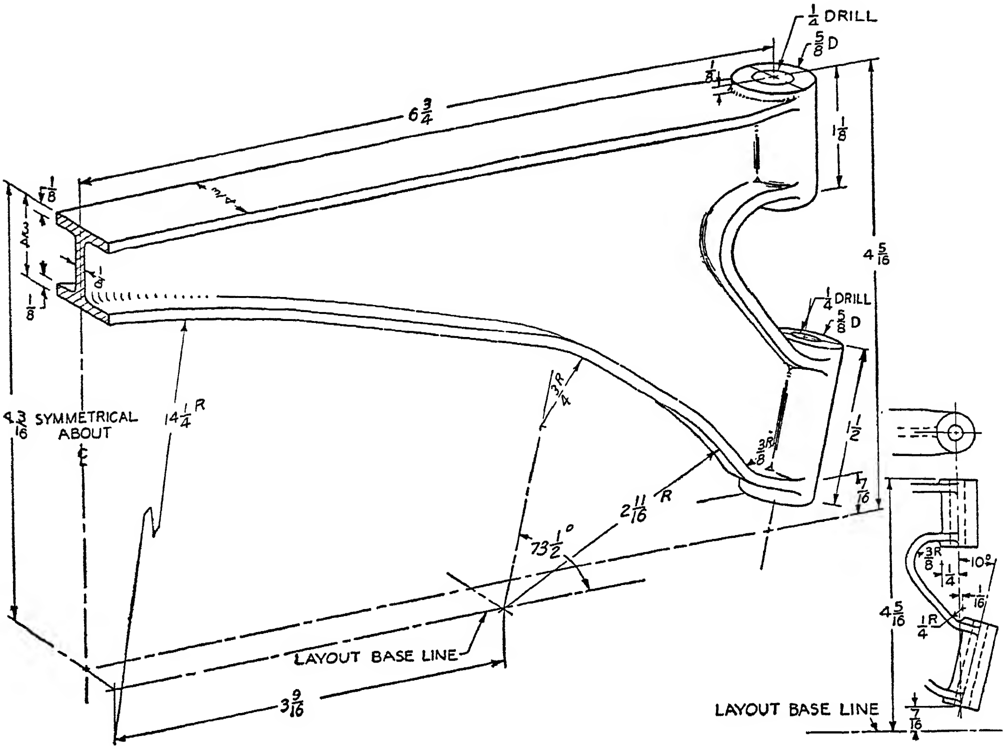


Fig. 12–44. Oil Tank Mounting Bracket. Prob. 12–14.

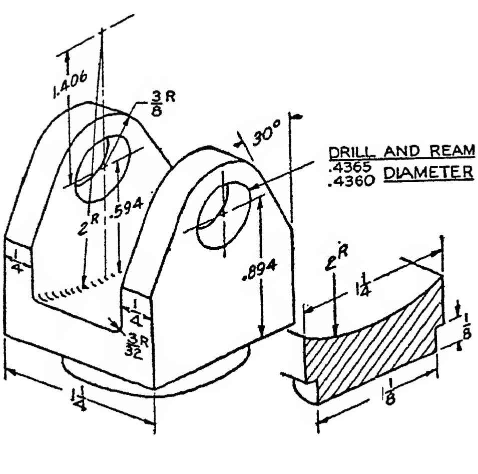


Fig. 12–45. Head. Prob. 12–15.

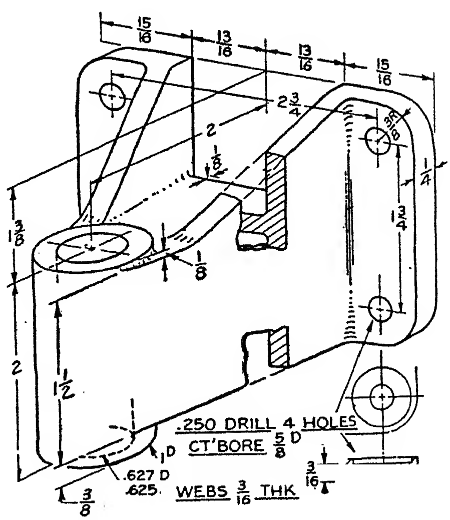


Fig. 12–46. Bracket. Prob. 12–16.

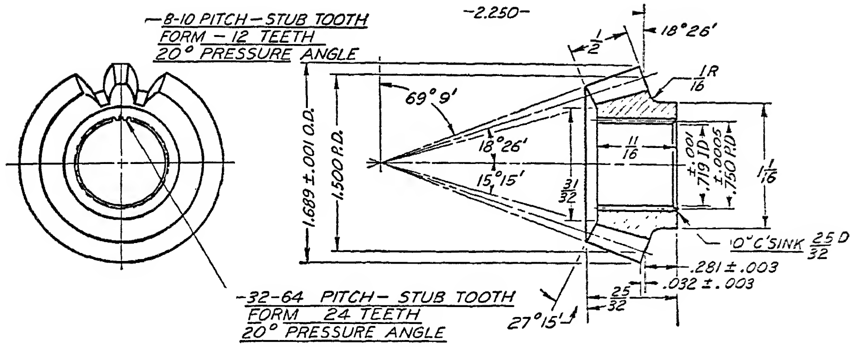


FIG. 12-47. Gear. Prob. 12-17.

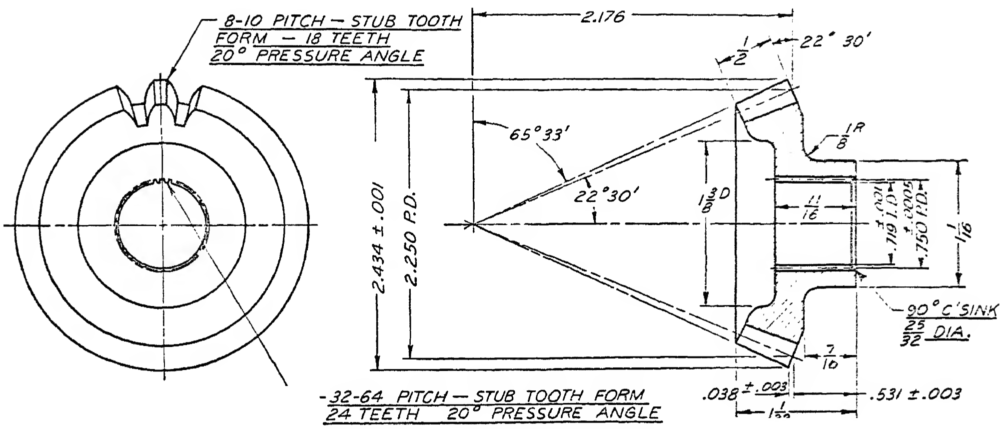


FIG. 12-48. Gear. Prob. 12-18.

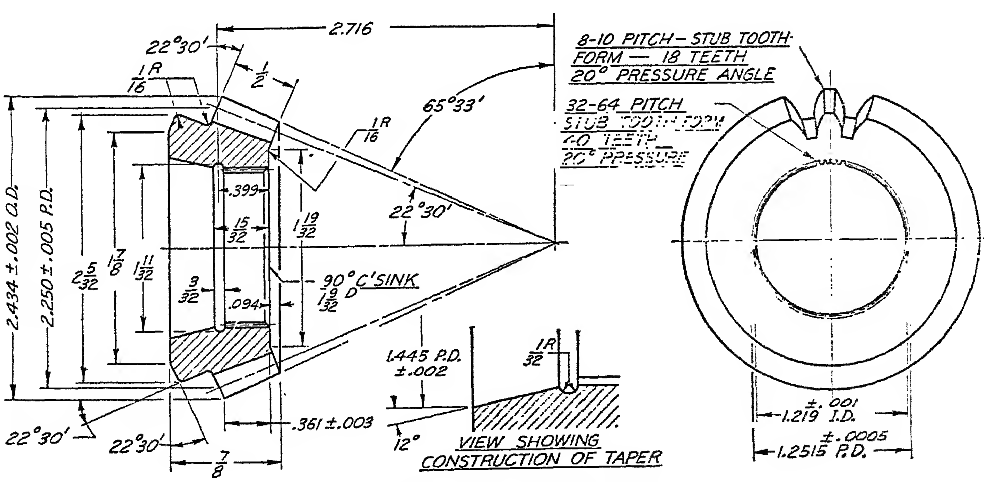


FIG. 12-49. Gear. Prob. 12-19.

Prob. 12–20. Fig. 12–50. — Make a WELD ASSEMBLY drawing for the Rudder and Brake Controls, Pedal Arm. Draw assembly full size, without the break shown. Make separate detail drawings of parts (–1), (–3), (–4) and (–5) as indicated on the layout (Fig. 12–51). Part (–1) is made from 1⅜ steel tube, .250 thick. Part (–3) is made from ⅞ steel tube, .156 thick. Material: Molybdenum steel (X4130). (Southern Aircraft Corporation.)

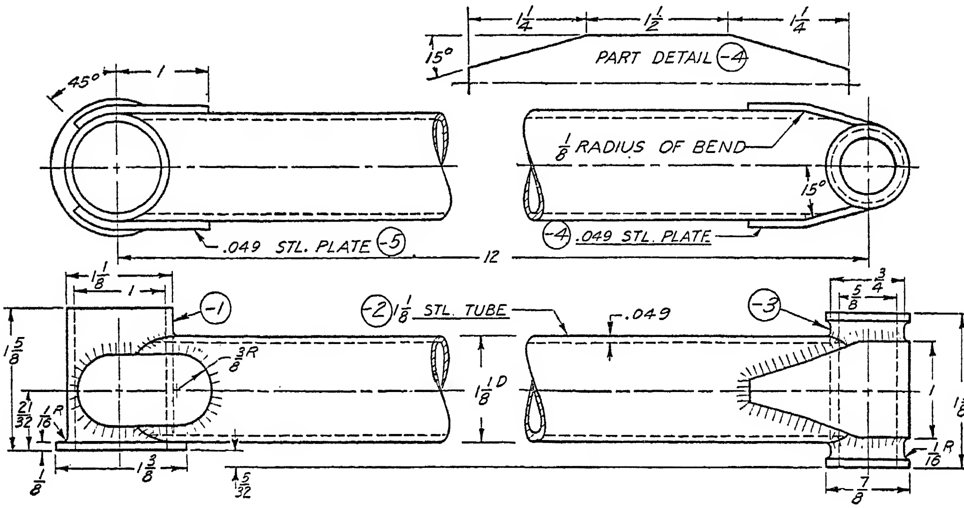


Fig. 12–50. Weld Assembly. Prob. 12–20.

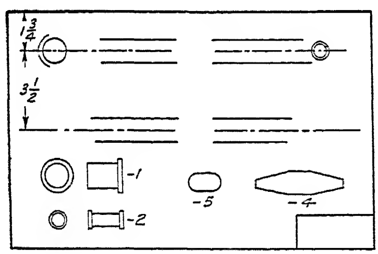


Fig. 12–51. Layout for Prob. 12–20.

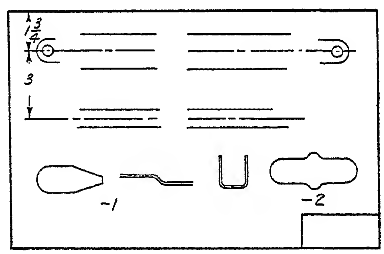


Fig. 12–52. Layout for Prob. 12–21.

Prob. 12-21. Fig. 12-53. — Make a WELD ASSEMBLY, Main Landing Gear, Lateral Brace Strut. Draw assembly full size, without the break shown. Make separate detail drawings for parts indicated on the layout (Fig. 12-52). Material: Molybdenum steel (X4130). (Southern Aircraft Corporation.)

Prob. 12-22. Fig. 12-1. — Make a detail drawing of the PLATE-BRACKET. Include a section on plane A–A as one of the views.

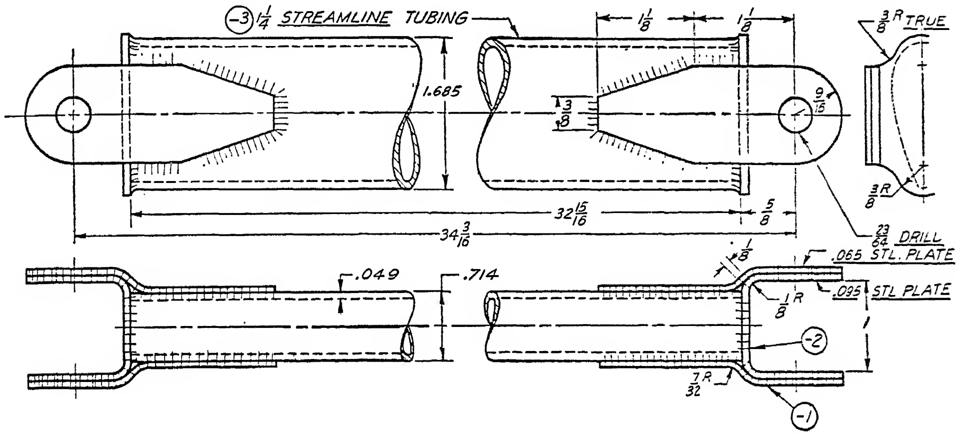


FIG. 12-53. Weld Assembly. Prob. 12-21.

CHAPTER XIII

SHEET METAL

13–1. Sheet materials and various extruded and formed shapes are used to a large extent in the manufacture of many of the parts of airplanes. Different methods of fastening such parts together are used, a number of which have been described in Chapter X.

Sheet materials are cut to a " flat pattern " and bent or formed to make the desired part. The basis of pattern layout is called development. Some methods are described in this chapter as well as some construction features which must be understood in order to make and read aircraft sheet metal drawings.

13–2. A " sheet metal " drawing is illustrated in Fig. 13–1. Note the part view at *A–A*, the flanges at *B–B*, stiffening at *C–C*, the lightening holes, flanges and section through a lightening hole at *D–D*, the riveting, the clips, and the fitting. Note also how the aluminum alloy sheets and sizes are given in the material list: AL. ALL. 24SO. Size .032 × 5⅛ × 10¾ and AL. ALL. 24SO. Size .025 × 5⅛ × 6¾. Observe the notes which call out the clips, fitting, holes, rivets, etc., and the tabulation for the rib contour as given near the upper left-hand corner. A number of other features of such drawings are illustrated and will be understood after a study of this chapter.

13–3. Templates and Patterns. — Templates and flat patterns are made of sheet metal for use in marking contours, outlines, and locating holes. Flange widths, bend allowances and metal thicknesses must be taken into consideration. Sometimes a flat pattern is laid out full size on a drawing and the print is used for a template (Fig. 13–2). On this drawing *B.U.* means bend up and *B.D.*, bend down. A number of features of such work is covered in this chapter beginning with Art. 13–19.

13–4. Materials include aluminum and alloys, the various kinds of steel, and copper and many of its alloys. Sheet metal gage dimensions are given in Table 17–3 (Chapter XVII).

A comprehensive presentation of fundamental information, tables and data for Alcoa aluminum is given in a publication of the Aluminum Company of America, *Alcoa Aluminum and its Alloys*, from which the following is quoted:

" As the metal is cold worked it becomes strain-hardened, the increase in strength and hardness depending on the amount of reduction which it receives. If it is subsequently heated to its annealing temperature, the effects of cold working are removed and the metal is in its soft temper, designated by the symbol O following the alloy designation, which in the case of Alcoa wrought alloys is a number followed by the letter ' S ' (2S). A letter preceding the alloy symbol indicates a minor change in composition from that of the basic alloy.

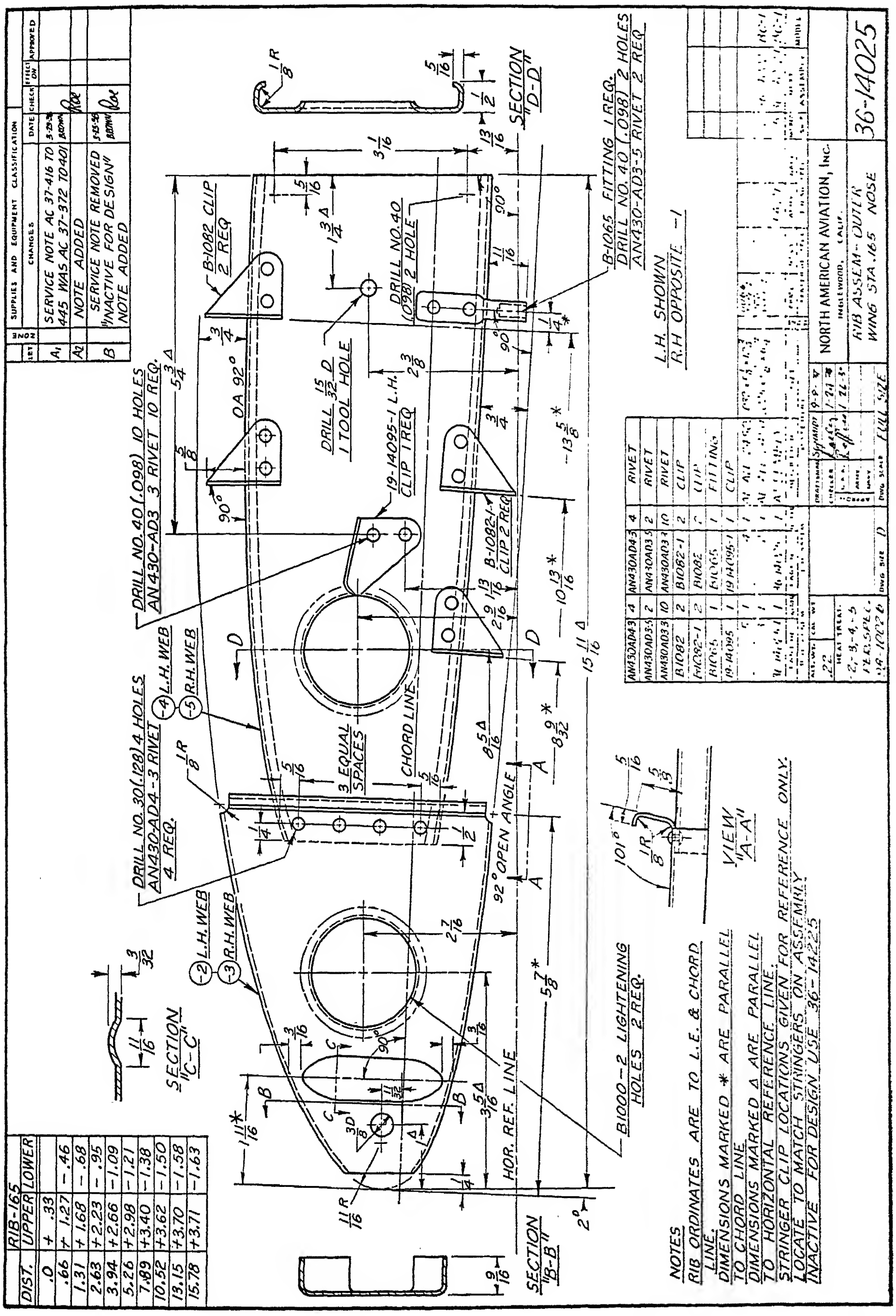


FIG. 13-1. A "Sheet Metal" Drawing.

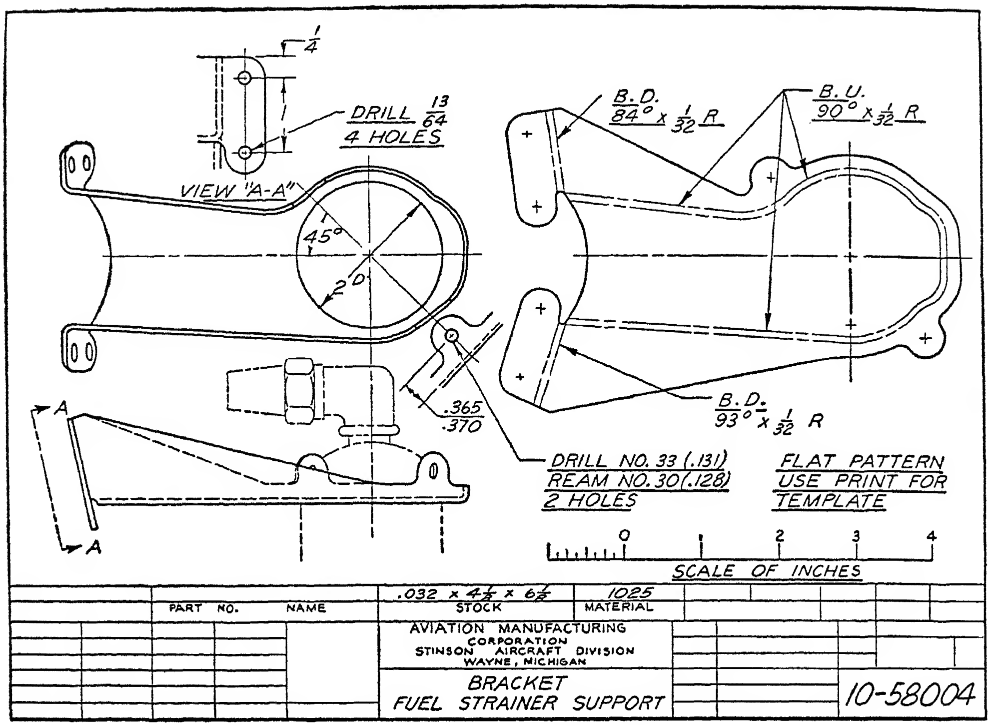


FIG. 13-2. Drawing with Flat Pattern. Prob. 13-49.

" In one class of alloys, the strain-hardening process is the only means of increasing the tensile properties. The alloys 2S, 3S, and 52S are of this type, and their various tempers are produced by subjecting them to definite reductions by cold work after they have been annealed during their fabrication.

" The hard temper, designated ' H,' is defined by the tensile properties which result from the maximum amount of cold working which it is practicable to perform with commercial fabricating equipment.

" Tempers intermediate between the soft and the hard temper are produced by varying the amount of cold work by proper choice of the thickness at which the metal is given its last annealing. The tempers are designated by the fractional symbols ' ¼H,' ' ½H ' and ' ¾H,' indicating an increase of the strength of the annealed alloy by the corresponding fraction of the spread between the soft and the hard tempers.

" These alloys (2S, 3S and 52S) are available in definite, controlled tempers other than soft ' O ' only in those commodities which are normally produced by cold work from the hot mill slab or bloom. The products which are included in this classification are sheet, tubing and wire.

" In another class of wrought aluminum alloys, improved mechanical properties are produced by heat treatment or by a combination of heat treatment and strain hardening.

" The symbol ' T ' following the alloy number indicates that the alloy is in its fully heat-treated and age-hardened condition. Some of the alloys (17S, A17S and 24S) age-harden fully on standing at room temperature after they have been quenched from the solution heat-treatment temperature. Others (53S, 61S) show some improvement in properties at room temperature, but to develop their maximum strength, they must be artificially aged by heating to a moderately elevated temperature.

" The wrought alloys are of two types: One, those in which the harder tempers are produced by strain hardening after annealing (2S, 3S, 52S and 56S): two, the heat-treatable alloys which,

as the name implies, respond to thermal treatments to improve their mechanical properties (17S, 24S, 53S, 61S, etc.)."

For composition of alloys of aluminum, see tables in Chapter XVII.

The steel classification of the Society of Automotive Engineers is used in specifications for all high grade steels employed in automotive and aircraft construction. An index system is used to identify the compositions of such steels. The first figure indicates the type of steel. For simple alloy steels, the second figure generally indicates the approximate percentage of the predominating alloying element and the last two or three figures indicate the average carbon content in *points*, or hundredths of one per cent.

GENERAL CLASSIFICATION

Carbon Steels	1xxx
High Manganese	T13xx
Nickel Steels	2xxx
Nickel Chromium Steels	3xxx
Molybdenum Steels	4xxx
Chromium Steels	5xxx
Chromium Vanadium Steels	6xxx
Tungsten Steels	7xxx and 7xxxx
Silicon Manganese Steels	9xxx

1025 Steel is identified as: 1 = carbon steel (first figure); 0 = no alloy (second figure); and 25 = carbon range of 0.20 to 0.30 per cent (last two figures).

In all cases, however, the latest S.A.E. (Society of Automotive Engineers) specifications should be used.

13–5. Flat Patterns. — Parts made up of plane surfaces or certain kinds of curved surfaces or combinations of surfaces may have the surfaces brought into successive contact with a sheet of paper or sheet metal upon which an outline can be drawn as illustrated in Figs. 13–3 and 13–4. This outline is called a development or *flat pattern* and when trimmed to shape it can be bent or rolled to form the part. A trimmed plate, or *template*, is used to scribe or mark out the pattern when a large number of identical parts are required.

13–6. Prism Type Patterns. — The rectangular tube of Fig. 13–5, is developed by laying off the distances 1–2, 2–3, 3–4, and 4–1 in succession on a straight line, all taken from the top view, and which added together are equal to the distance around the tube. At each of the points 1, 2, 3, etc., draw perpendiculars equal in length to the vertical edges by projecting horizontally from the front view. Join the upper ends of the perpendiculars to complete the flat pattern. If any of the surfaces are cut between the edges, draw false edge lines as at *A* and *B* in Fig. 13–6 and proceed as indicated.

13–7. Cylinder Type Patterns. — The circular tube of Fig. 13–7 is developed by locating elements (false edges) in the top view, projecting them to the front view and then proceeding as for a prism except that a smooth curve is drawn

through the tops of the perpendiculars on the flat pattern. The work is simplified by taking the elements equal distances apart in the top view. The stretchout is equal to the circumference. Other cylindrical surfaces are worked out in the same manner as indicated in Fig. 13–8.

Elbows are composed of cylinders. To lay out a four-piece elbow, draw the limiting lines *ob* and *od*, and the arcs *ca* and *db* (Fig. 13–9 at I). Divide the arcs into one less than the number of pieces in the elbow as at II. Bisect the divisions and draw radial lines as at III. These radial lines are the joint lines of the elbow

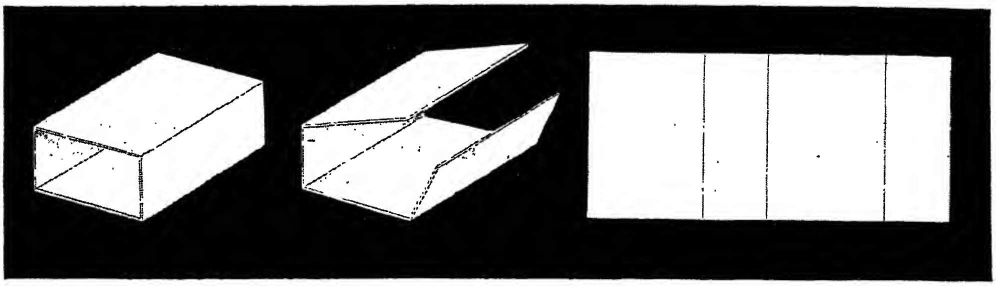


FIG. 13–3. Flat Pattern for Rectangular Tube.

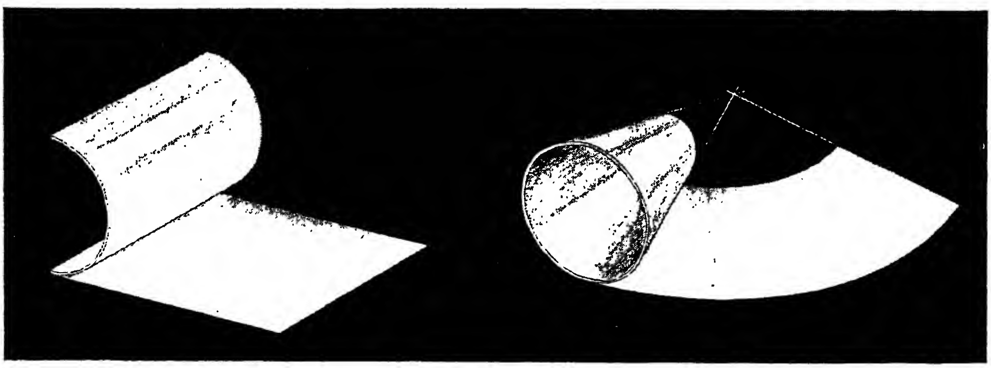


FIG. 13–4. Flat Pattern for a Half Cylinder and a Frustum of a Cone.

Draw tangents to the arcs as at IV and complete the view as at V. Other elbows are indicated in the figure.

13–8. Flat Patterns for Elbows. — The stretchout for each piece of an elbow is equal to the perimeter (circumference of circle) of a right section. The first piece is developed as explained for the cylinder in Fig. 13–10. The stretchout for the middle piece (b_1–b_1) is generally located as shown with distance e_1, b_1 equal to *ab*. True lengths of the elements are obtained from the front view. The spacing of the elements is obtained from the " construction semicircle " shown below the front view. Note that the middle piece is equal to two of the end

pieces and is cut on the element *ca*, while the end pieces are cut on the elements *gf* and *el*.

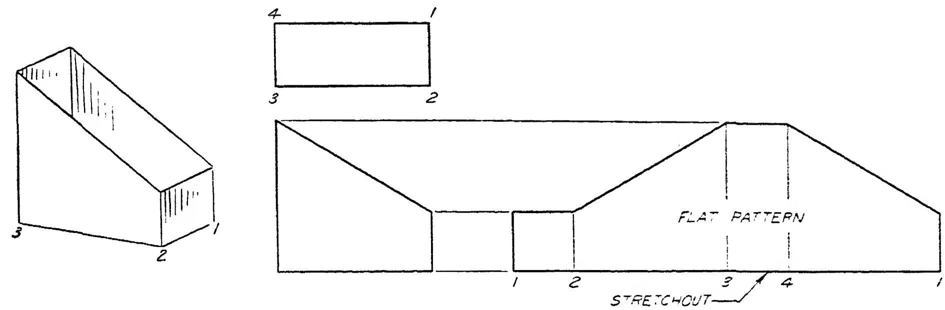


FIG. 13–5. Flat Pattern. Rectangular Tube.

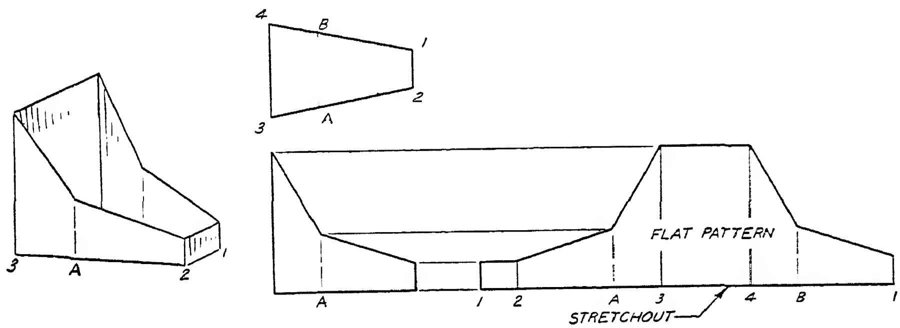


FIG. 13–6. Flat Pattern. Special Tube.

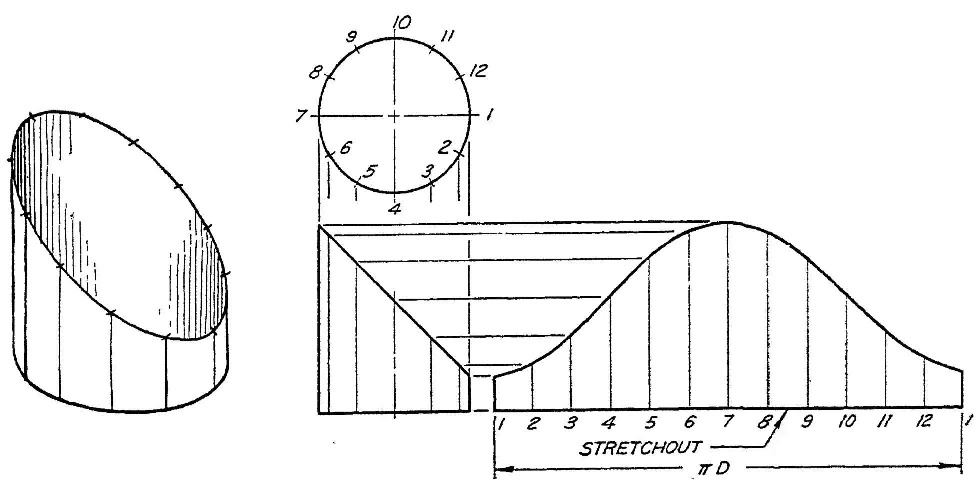


FIG. 13–7. Flat Pattern. Cylinder.

13–9. True Length of a Line. — The determination of true lengths is a necessary part of aircraft drafting — lengths of struts, rods, pipes, wires, etc., as well as edges and layout lines on flat patterns. When a line is parallel to one of the principal planes it will show in its true length in a view on that plane. When it is not parallel it may be revolved until it is parallel or it may be revolved into a plane.

This is illustrated in Figs. 13–11 and 13–12 each of which shows the picture of an oblique line AB at **1** and two views of the line at **2.** In Fig. 13–11 at **1** a

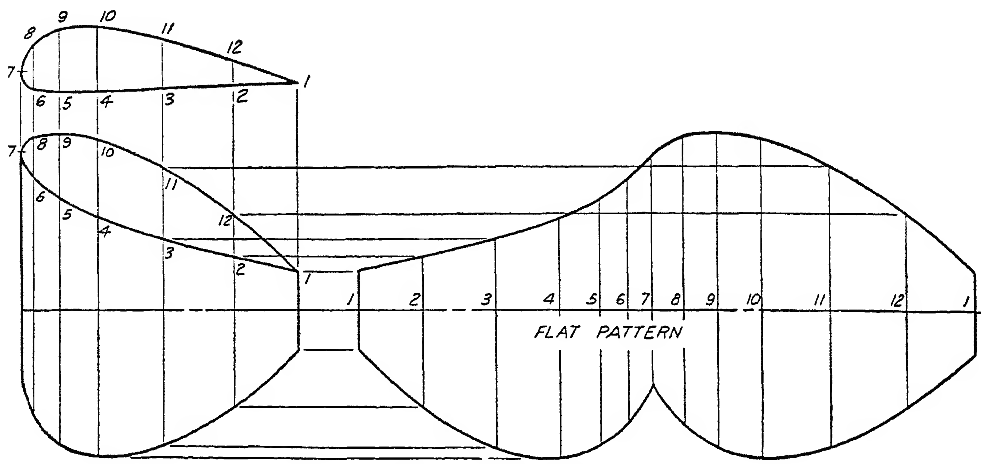


Fig. 13–8. Flat Pattern.

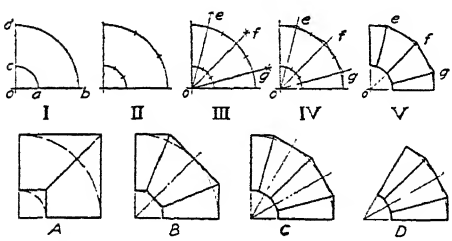


Fig. 13–9. Layout for Elbows.

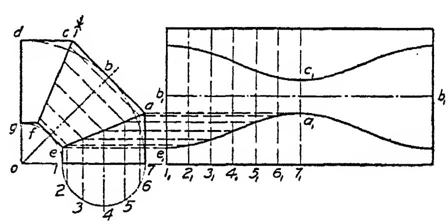


Fig. 13–10. Three-piece Elbow.

vertical axis AO, the projection OB, and the line, form a right triangle which can be revolved about the axis to describe a right circular cone. Since all the elements of such a cone are equal, the contour element will show the true length of the line AB. The orthographic views are shown at **2** in Fig. 13–11, where the path of revolution shows in the top view and the true length is shown in the front view at $A_F B_F'$ (the revolved position of the line).

In like manner a line has been revolved about a horizontal axis in Fig. 13–12.

13–10. The true length of a member of an engine mount is indicated in the diagrams of Fig. 13–13, a picture at **1,** the orthographic views at **2** where AB

has been revolved to show the true length at $A_R'B_R$, and the right circular cone construction at **3** with the true length at $A_R'B_R$.

13-11. Tapered Type Patterns. — The pyramid of Fig. 13-14 is developed by laying out the faces in their true size and in successive order. In this case

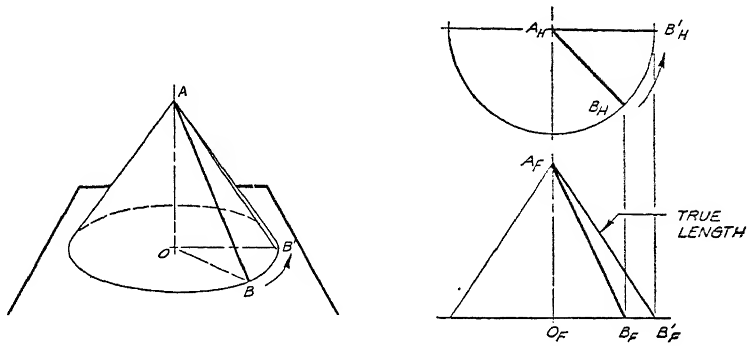


FIG. 13-11. True length of a Line.

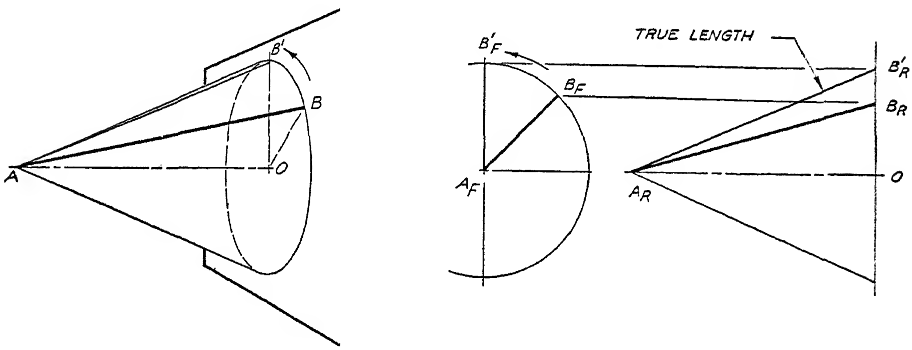


FIG. 13-12. True Length of a Line.

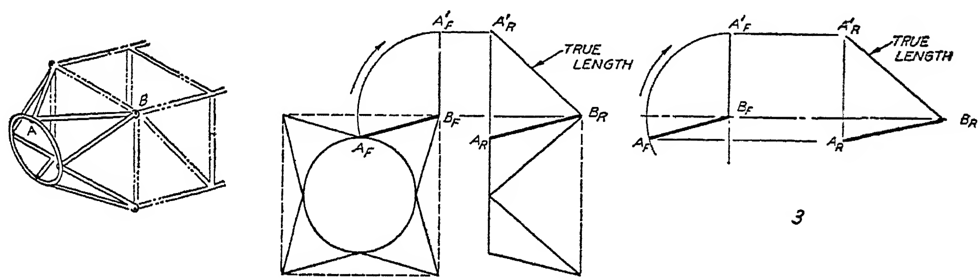


FIG. 13-13. Engine Mount.

there are three equal triangular faces. The edges of the base show in the top view. The lateral edges are the same length and equal to the true length shown at O_F1_F as this edge is parallel to the front plane. From any point O draw a

measuring arc with radius $O1 = O_F1_F$. Space off chords 1–2, 2–3, and 3–1, equal to 1_H2_H, 2_H3_H, and 3_H1_H. Draw radial lines. The base shows in its true size in the top view and can be added to the flat pattern if required.

13–12. The edges of the right square pyramid of Fig. 13–15 are equal but they do not show in their true length. To develop the lateral surface, revolve

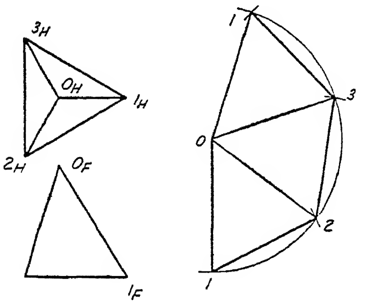


FIG. 13–14. Flat Pattern. Pyramid.

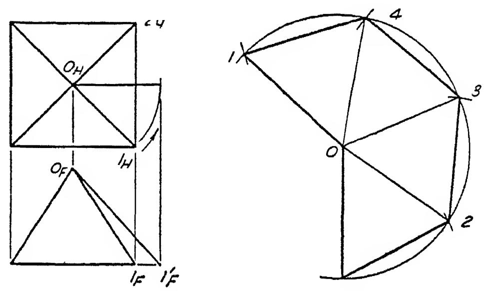


FIG. 13–15. Flat Pattern. Pyramid.

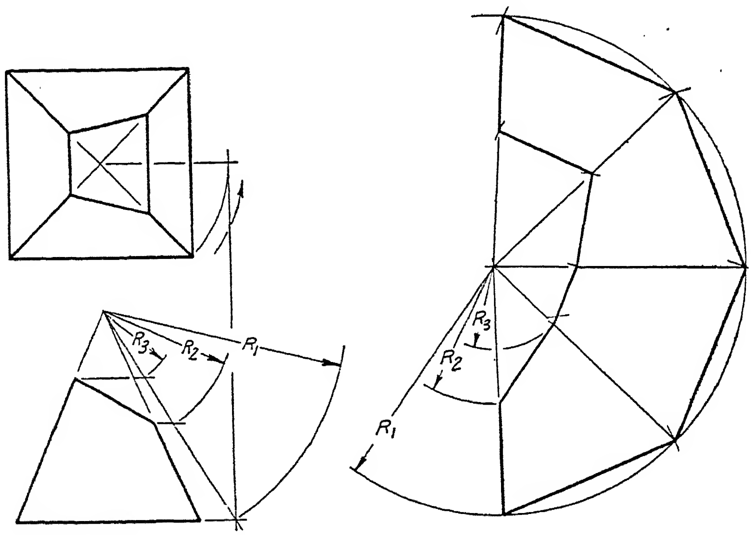


FIG. 13–16. Flat Pattern. Pyramid.

one edge to find its true length as shown (O_F1_F'). Use this true length as the radius of the measuring arc and proceed in the regular way.

For the truncated pyramid (Fig. 13–16) draw the flat pattern for the complete pyramid, then find the true lengths of the edges from the apex to the cut and measure them off on the flat pattern as shown (R_1 = measuring arc for complete pattern, R_2 and R_3 are true lengths from the apex to the cuts).

13–13. The right circular cone of Fig. 13–17 is developed by assuming the surface to be made up of a number of equal triangles and proceeding as for a right pyramid. Divide the circumference of the base into a number of equal parts and draw elements of the cone. Since all the elements are equal the contour element in the front view is the radius of the measuring arc.

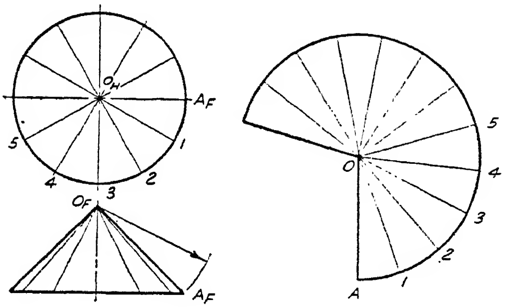


FIG. 13–17. Flat Pattern. Right Circular Cone.

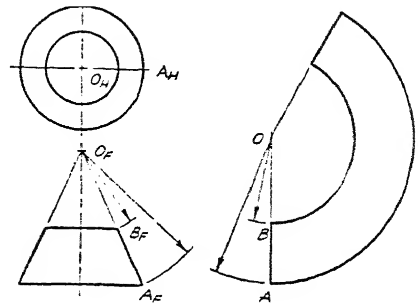


FIG. 13–18. Flat Pattern. Frustum of Right Circular Cone.

This is called the triangulation method. When used for curved surfaces it is approximate but can be made sufficiently accurate by careful spacing of the arcs.

A frustum of a right circular cone is developed in Fig. 13–18.

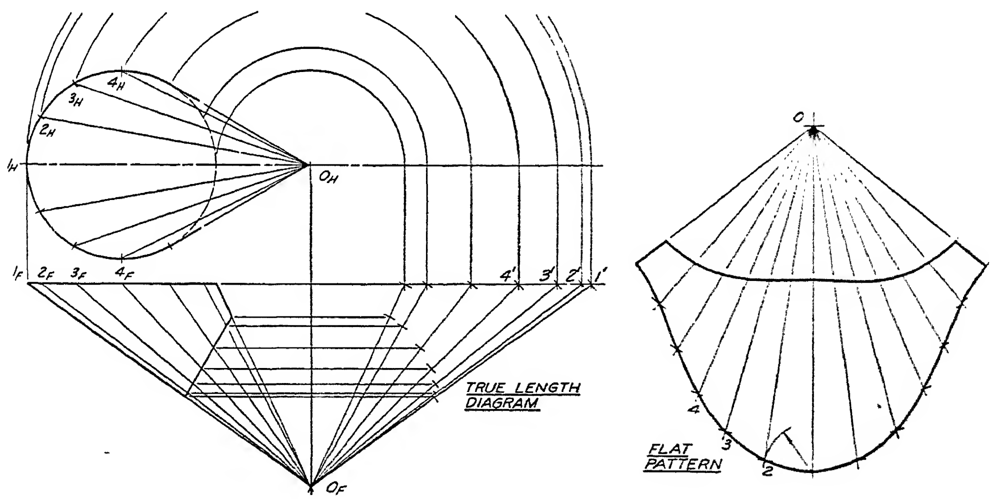


FIG. 13–19. Flat Pattern. Oblique Cone.

13–14. A truncated oblique cone is shown in Fig. 13–19. Divide the circumference of the base into a number of equal parts and draw elements of the cone. Construct a true length diagram for the elements, assuming the cone to be complete. For the development, draw O–1 $= O_F1'$ taken from the true length diagram. With O as a center draw a short arc with O_F2' as a radius, and with 1

as a center and radius $1_H 2_H$ draw another arc intersecting the first to locate point 2. Proceed in this way to locate successive points until all approximate triangles have been drawn in order. Draw a smooth curve through points 1, 2, 3, etc. In like manner determine the true lengths of the portions of the elements, lay them off on the corresponding elements, and draw a smooth curve to complete the flat pattern. Oblique pyramids, complete or truncated, are developed in a similar manner, using a true length diagram.

13–15. Flat patterns for many kinds of surfaces can be drawn by dividing them into triangles, finding the true length of the sides of the triangles and laying them out in the proper order. An exhaustive treatment of developments will be found in the author's *Drafting for Engineers*.

13–16. Lines of intersection (Fig. 13–20) between surfaces in general present little difficulty but in some cases it is necessary to use a systematic method of locating points on the line or curve. Such methods are explained in detail in *Drafting for Engineers*.

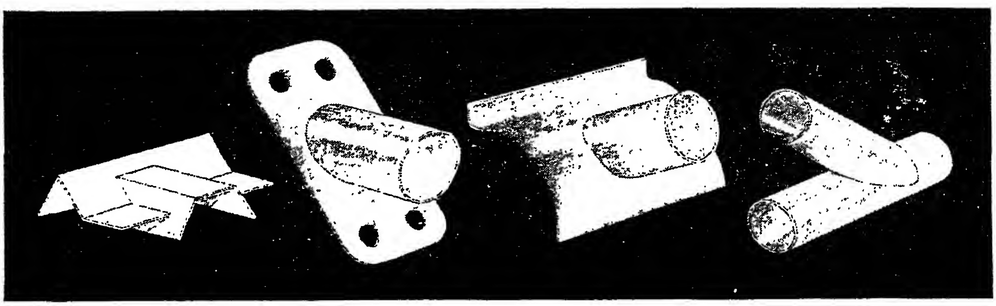


FIG. 13–20. Intersections.

Plane surfaces intersect in straight lines, plane and curved surfaces may intersect in straight or curved lines depending upon the position and character of the surfaces and the same is true of intersecting single curved surfaces.

13–17. Plane Surfaces. — A picture and three views are shown in Fig. 13–21 where X, Y and Z represent the edges of three vertical planes. Plane X contains the front edge (or line) of the vertical piece and cuts a horizontal line from the other piece. These two lines on plane X intersect at A_F in the front view and locate a point on the line of intersection. Plane Y contains the top line of the horizontal piece and cuts a vertical line from the other piece. These two lines intersect at B_F, a point on the line of intersection. Plane Z coincides with a plane of the vertical piece and intersects the other piece in a horizontal line shown as a hidden line through C_F in the front view.

13–18. Cylindrical Surfaces. — To find the line of intersection between two cylinders (Fig. 13–22) pass planes to cut lines (elements) from both cylinders. Elements on plane W intersect at A_F in the front view. Planes X and Y cut two

elements from the vertical cylinder which intersect horizontal elements in the front view. Plane Z cuts elements which locate the highest points on the curve. More cutting planes would, of course, be necessary to obtain sufficient points for a smooth curve.

The intersection of two cylinders at an angle and with non-intersecting axes is shown in Fig. 13–23. Cutting planes are used to cut elements from both cylinders, which intersect to locate points on the curve of intersection. Note that planes V, X, Y, and Z are limiting planes which pass through the contour elements and so locate the limits of the curve.

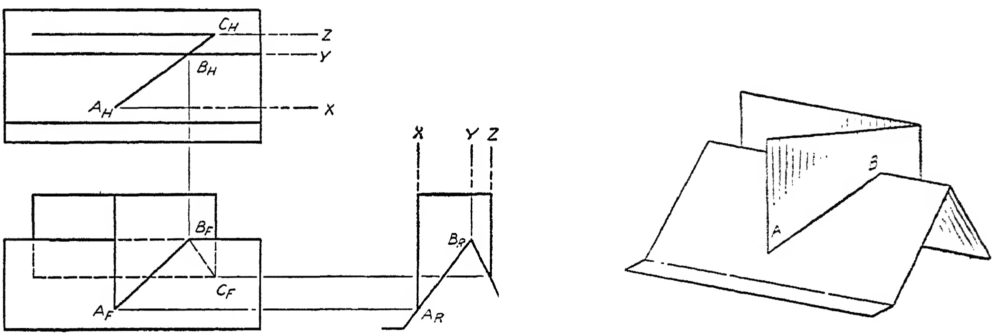


FIG. 13–21. Intersections. Plane Surfaces.

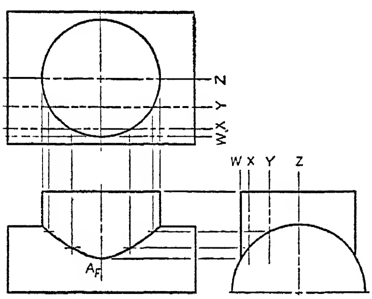


FIG. 13–22. Intersections. Cylinders.

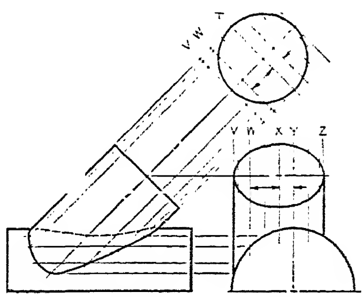


FIG. 13–23. Intersections. Cylinders.

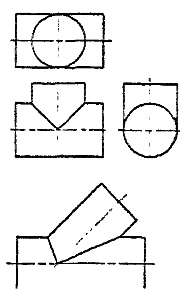


FIG. 13–24. Intersections. Cylinders.

Some intersections for cylinders of the same diameter with intersecting axes are indicated in Fig. 13–24.

13–19. A prism, a cylinder, and a cone cut by planes at an angle are shown in Fig. 13–25. The points in which lines or elements pierce the plane can be seen in the edge view of the plane and projected to the other view. The true size of an inclined face can be found by drawing an auxiliary view (Chapter VII).

13–20. Bend Relief, Flanges, etc. — Flat sheets and formed parts are built up into aircraft parts in a variety of ways. Sheet metal flanges are bent up or down

or at an angle (Fig. 13–26). *Bend radii* are a part of engineering design practice and such data should be consulted for the material and thickness used in a given case. Minimum bend radii (Fig. 13–27) vary from 1/16 for thicknesses of less than .032 to 1/4 for .125 thickness. The mold line is a theoretical edge which would be formed by extending the surfaces to intersect as indicated in Fig. 13–27, which also shows the bend line (tangent bend line). *Flange widths* (Fig. 13–28) formed on a power brake require certain minimum widths which must be pro-

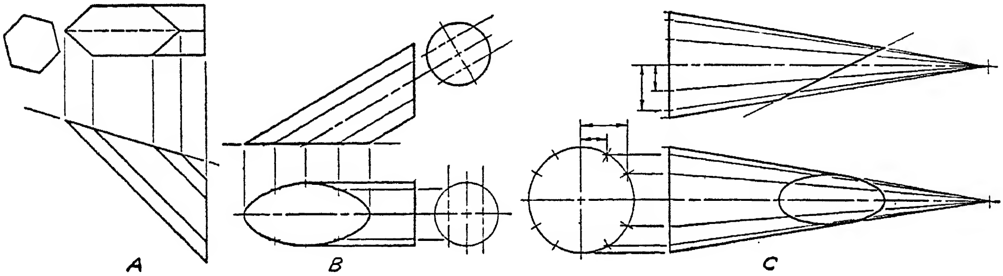


Fig. 13–25. Plane Intersections.

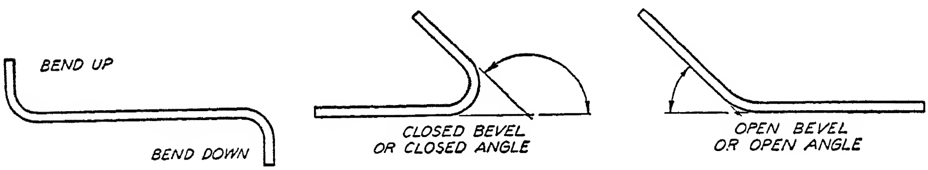


Fig. 13–26. Bends.

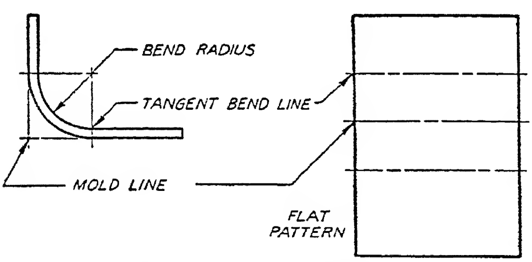


Fig. 13–27. Bend Radius.

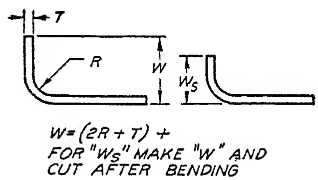


Fig. 13–28. Flange.

vided (and cut off if less width is required). When two bends meet as at a corner it is necessary to provide bend relief in order to prevent cracking and distortion (Fig. 13–29).

13–21. Joggles. — A joggle is an offset in a sheet, flange or extruded shape (Fig. 13–30). The length of joggle should be from three to four times the depth or offset. Soft material is required in general (SO condition). If ST condition, " anneal " should be called out before forming and " heat treat " afterward. Joggling is undesirable and should be avoided if possible. If the

offset is .032 or less, joggling is not generally used except where exposed to air flow. The joggle radii are not given on the drawing but the amount of the offset should be given. Dimensions will depend upon conditions and the company practice.

13–22. Joints. — Methods of joining metal parts include soldering, brazing, welding (acetylene, electric arc, and resistance) riveting and seaming (Fig. 13–31).

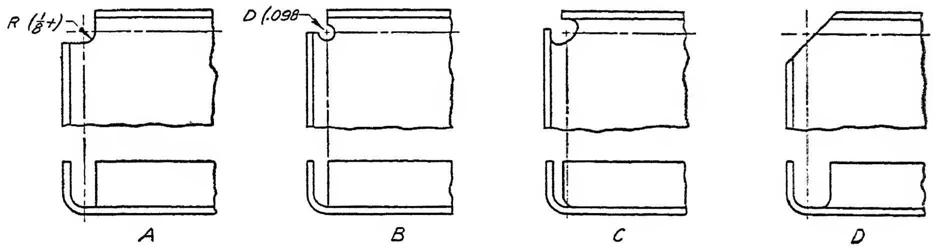


Fig. 13–29. Bend Relief.

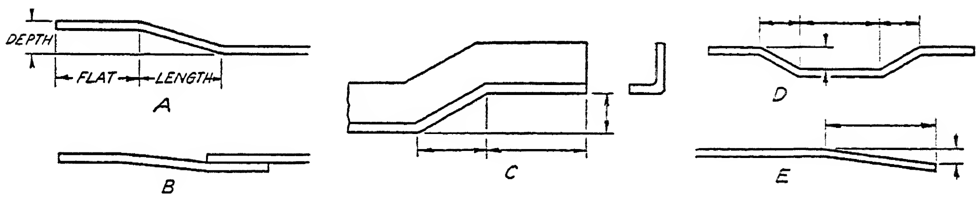


Fig. 13–30. Joggles.

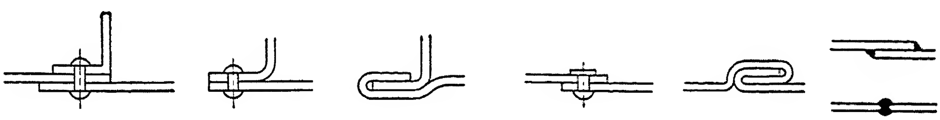


Fig. 13–31. Joints.

13–23. Dimensioning Sheet Metal Parts. — The treatment of dimensioning given in Chapter XI applies in general to sheet metal parts. Some exceptions and specific dimensioning requirements for sheet metal parts are covered in the following quotation from the Lockheed Drafting Manual.

" 32nds have been accepted as the smallest fractional dimension on sheet metal parts. 64ths may be used in exceptional cases. Decimal dimensions should be used for all formed contours.

" Dimensions should be to the same side of the metal (Fig. 13–32).

" Dimensions on sheet metal parts will be given to mold lines (Fig. 13–33).

" *Excess dimensions.* The sheet section shown in Fig. 13–32 at *A* is over dimensioned for the following reasons. The triangular portion of Fig. 13–32 at *A* is given four dimensions, one angular and three linear. Generally two dimensions, as shown in Fig. 13–32 at *B* and *C*, are the most useful. Angular dimensions are not necessarily useful in making tools for parts such as these, as the angle may be scaled or computed by the template department. However, in the case of flanges, an angular dimension is necessary (Fig. 13–33). Closed dimensions, that is

a series of consecutive dimensions tied in with an over-all as shown at the base of Fig. 13–32 at *A*, are to be avoided. Almost every series of dimensions includes one point whose location is not critical and which may be allowed to vary the amount of the tolerance buildup involved. This permissible variation allows more economical production in the shop and permits faster inspection. This undesirable feature may be eliminated by removing one of the flange dimensions as illustrated in Fig. 13–32 at *B*, or the over-all dimension may be omitted, as at *C*.

" *Offsets.* To dimension a flat planform use offsets, not angles, as in Fig. 13–34.

" *Joggles.* All joggles not called out as a DS standard shall be dimensioned from the original mold line of the part. The length of the flat surface of the joggle and the joggle allowance shall be dimensioned (Fig. 13–35).

" *Flange angles.* All sheet metal flange angles shall be dimensioned by showing the outside angle (Fig. 13–33).

" *True angles.* A true angle can only be measured in a plane which is perpendicular to a mold line. However, no angle shall be designated as ' true ': a section shall be taken where the true angle is not already shown in the plane of the paper. Dimensions on surfaces which are not

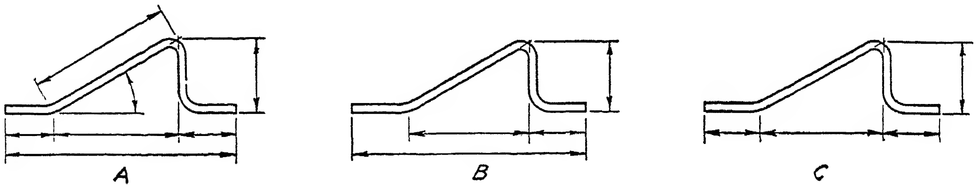


Fig. 13–32.

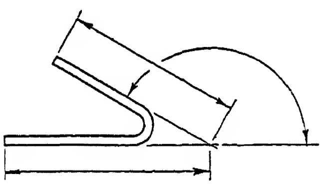


Fig. 13–33.

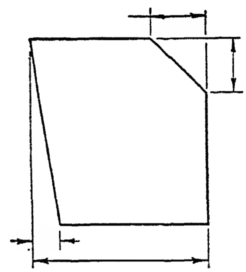


Fig. 13–34.

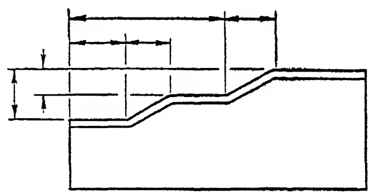


Fig. 13–35.

in the drawing but which are taken in the plane of the metal (other than angles) should be clearly marked IN THE PLANE OF METAL.

" *Dimensioning of holes.* When a part requires several holes to be drilled in a series, and all are equally spaced, the holes may be dimensioned as shown in Fig. 13–36 at *A*. In cases where it is not practical to combine an operation note with a dimension of a series of holes, rivets, etc., the holes may be dimensioned thus — ' 10 SPACES 3/4 C.C.' Where the overall dimension is necessary in spacing the holes, a notation as shown in Fig. 13–36 at *B* should be used.

" Approximate spacings on rivet and bolt layouts should be avoided where possible (Fig. 13–36 at *C*).

" A note triangle may be used advantageously where several rows of holes, rivets, etc., are used on the same drawing. This note triangle shall refer to a general note to the left of the title block similar to Fig. 13–36 at *D*.

" *Contoured surfaces.* On contoured surfaces dimensions applying to outside curvature will be placed on the outside of the curve. Those applying to inside of curvature will be placed on inside of the curve (Fig. 13–37).

" *Assembly dimensions.* In general, when it is necessary to locate holes, rivets, cutouts, etc., on assembly drawings the dimensions shall be tied in with some measureable point on the

largest piece in the assembly, or from a reference line such as the fuselage reference line, station line, etc.

" Edge distances, etc., should be taken from the heel of the angle. This applies to both sheet and extruded parts (Fig. 13-38).

" *Junction box dimensions.* Holes located in the sides of junction boxes should be dimensioned from the bottom of the box."

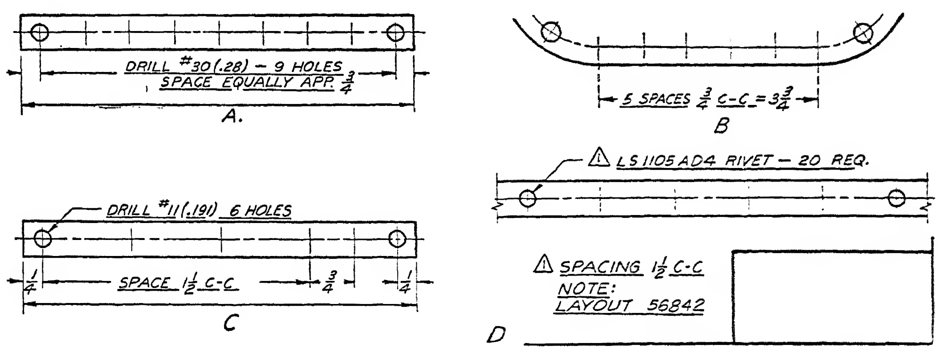


Fig. 13-36.

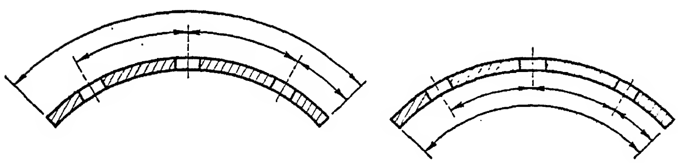


Fig. 13-37.

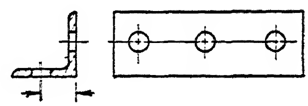
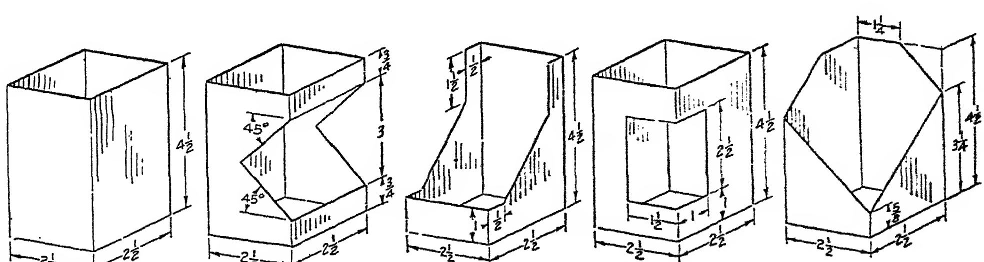


Fig. 13-38.

13-24. PROBLEMS. — A selection from Problems 13-1 to 13-46 should be worked out to obtain a good idea of the principles involved in laying out flat patterns. Following this, complete drawings should be made for a number of the drawings indicated in Problems 13-47 to 13-58. Certain dimensions are to be worked out on the drawings as made. This will require reference to the text of this chapter, to Chapter XVII, and to such other data as may be available.

Probs. 13-1 to 13-5. Fig. 13-39. — Draw the necessary views and flat patterns (developments) of the square tubes.



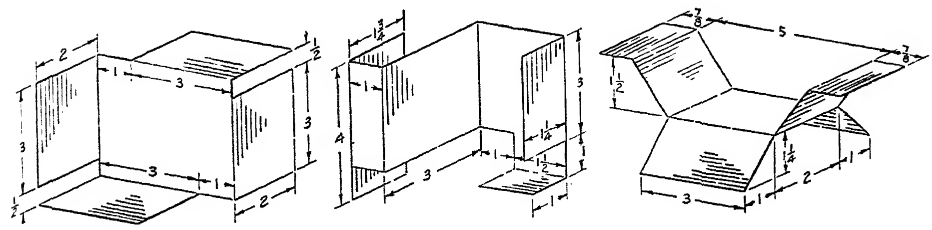
Prob. 13-1. Prob. 13-2. Prob. 13-3. Prob. 13-4. Prob. 13-5.

Fig. 13-39

Probs. 13-6 to 13-8. Fig. 13-40. — Draw the necessary views and flat patterns (developments) of surfaces shown.

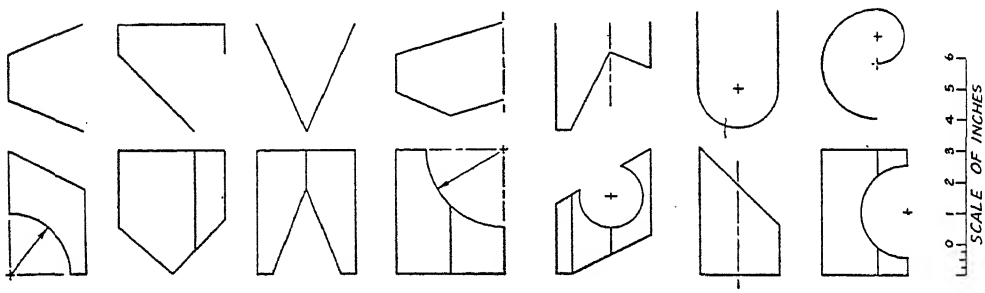
Probs. 13-9 to 13-15. Fig. 13-41. — Draw the necessary views and flat patterns for the surfaces shown. Use graphic scale.

Probs. 13-16 to 13-21. Fig. 13-42. — Draw the necessary views and flat patterns for the surfaces shown. Use graphic scale.



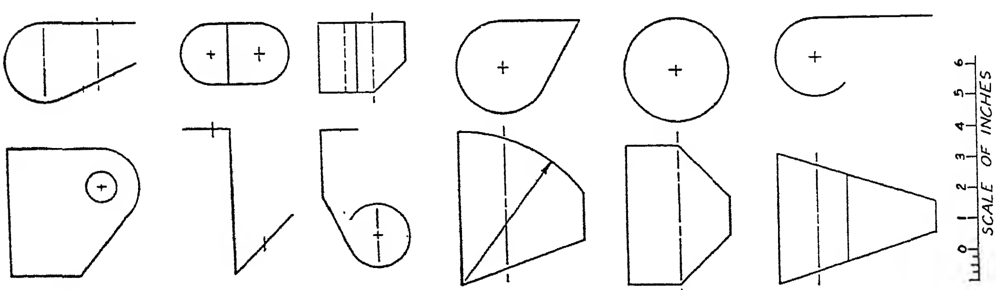
Prob. 13-6. Prob. 13-7. Prob. 13-8.

FIG. 13-40.



Prob. 13-9. Prob. 13-10. Prob. 13-11. Prob. 13-12. Prob. 13-13. Prob. 13-14. Prob. 13-15.

FIG. 13-41.



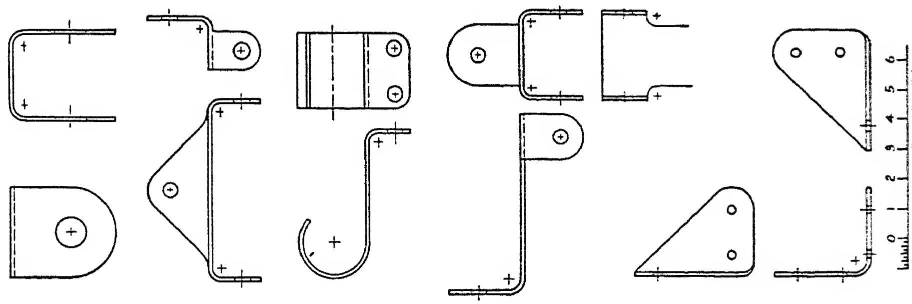
Prob. 13-16. Prob. 13-17. Prob. 13-18. Prob. 13-19. Prob. 13-20. Prob. 13-21.

FIG. 13-42.

Probs. 13-22 to 13-26. Fig. 13-43.— Draw the necessary views and flat patterns for the sheet metal parts shown. Use graphic scale.

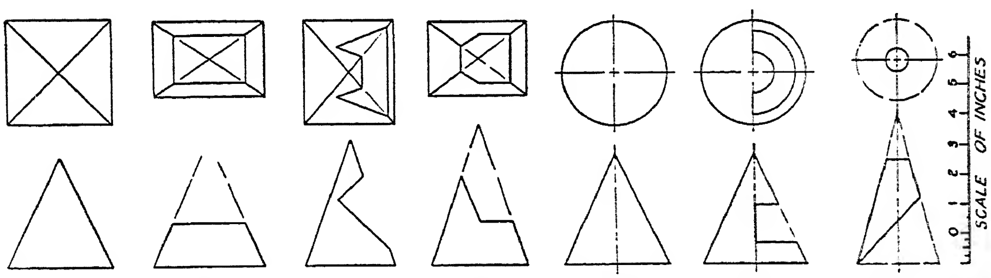
Probs. 13-27 to 13-33. Fig. 13-44. — Draw the necessary views and flat patterns for the surfaces shown. Use graphic scale.

Probs. 13-34 to 13-36. Fig. 13-45. — Draw the necessary views and the intersection of the cylindrical tube *A*, hexagonal tube *B*, or special tube *C* with the flat plate. Develop the cylinder or tube. Use graphic scale shown at the right of Fig. 13-46.



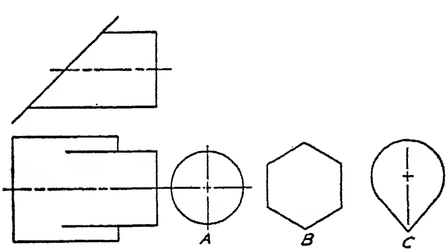
Prob. 13-22. Prob. 13-23. Prob. 13-24. Prob. 13-25. Prob. 13-26.

Fig. 13-43.



Prob. 13-27. Prob. 13-28. Prob. 13-29. Prob. 13-30. Prob. 13-31. Prob. 13-32. Prob. 13-33.

Fig. 13-44.



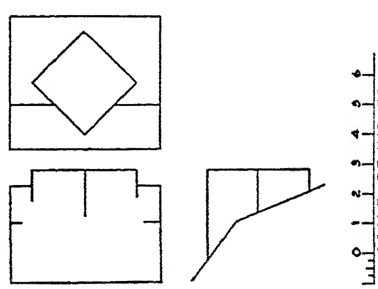


Fig. 13-45. Probs. 13-34, 13-35, 13-36. Fig. 13-46. Prob. 13-37.

Probs. 13–37 to 13–39. Figs. 13–46 to 13–48. — Draw the necessary views, find the line of intersection, and draw flat patterns. Use graphic scales.

Probs. 13–40 to 13–42. Fig. 13–49. — Draw the necessary views, find the line of intersection and draw flat patterns. Prob. 13–40, when $X = \frac{3}{8}$. Prob. 13–41, when $X = \frac{1}{8}$. Prob. 13–42, when $X = 0$. Use graphic scales as needed.

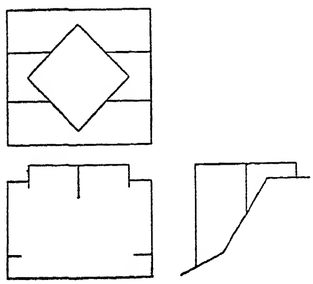


Fig. 13–47. Prob. 13–38.

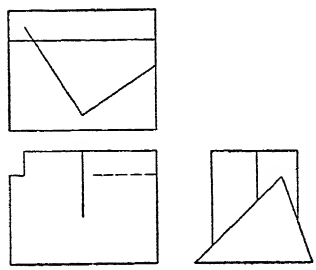


Fig. 13–48. Prob. 13–39.

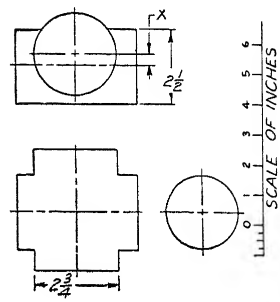


Fig. 13–49. Prob. 13–40.

Prob. 13–43. Fig. 13–50. — Draw the necessary views, find the line of intersection and draw flat patterns. Use graphic scale at right of Fig. 13–51.

Probs. 13–44 to 13–46. Fig. 13–51. — Draw the necessary views, find the line of intersection and draw flat patterns for the surfaces. Prob. 13–44, cylindrical tube. Prob. 13–45, square tube. Prob. 13–46, triangular tube.

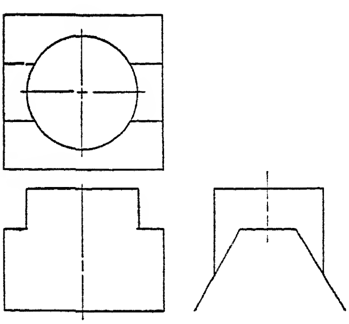


Fig. 13–50. Prob. 13–43.

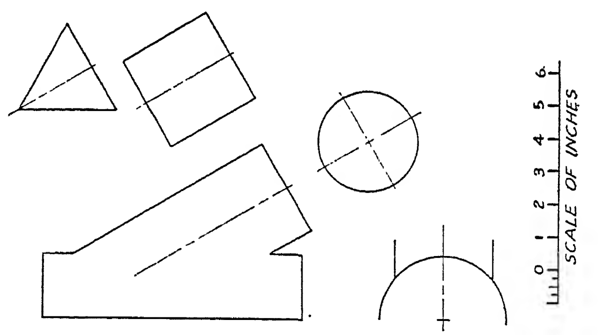


Fig. 13–51. Probs. 13–44, 13–45, 13–46.

Prob. 13–47. Fig. 13–52. — Make a drawing of the AIR DUCT (OUTLET) as shown and lay out flat patterns. Base (-1) to be welded to (-2) and (-2) to be welded to (-3). All material, .035 steel, No. 4130.

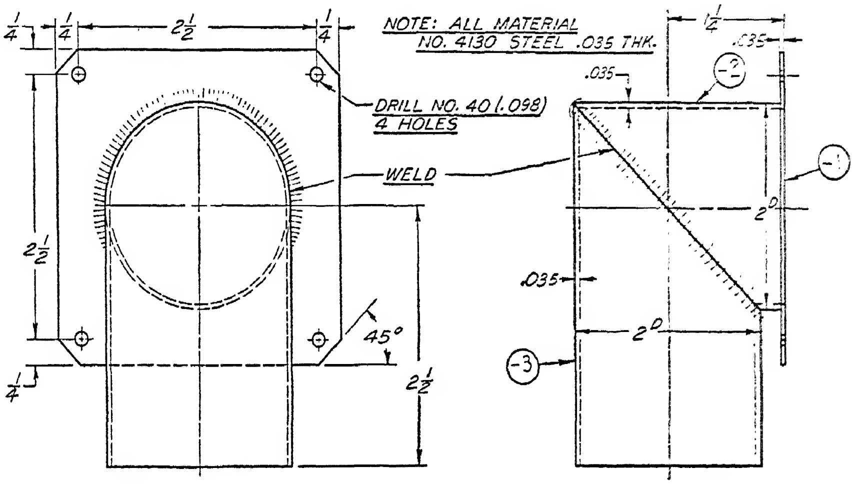


FIG. 13–52. Prob. 13–47.

Prob. 13–48. Fig. 13–53. — Make a detail drawing of the SUPPORT, Rudder Pedal, as indicated on the layout, including a flat pattern. (Engineering and Research Corporation.)

Prob. 13–49. Fig. 13–2. — Make a drawing and flat pattern for the BRACKET — Fuel Strainer Support, as indicated. Use the graphic scale to obtain dimensions. Check your drawing and adjust as necessary. (Stinson Aircraft Division, Aviation Manufacturing Corporation.)

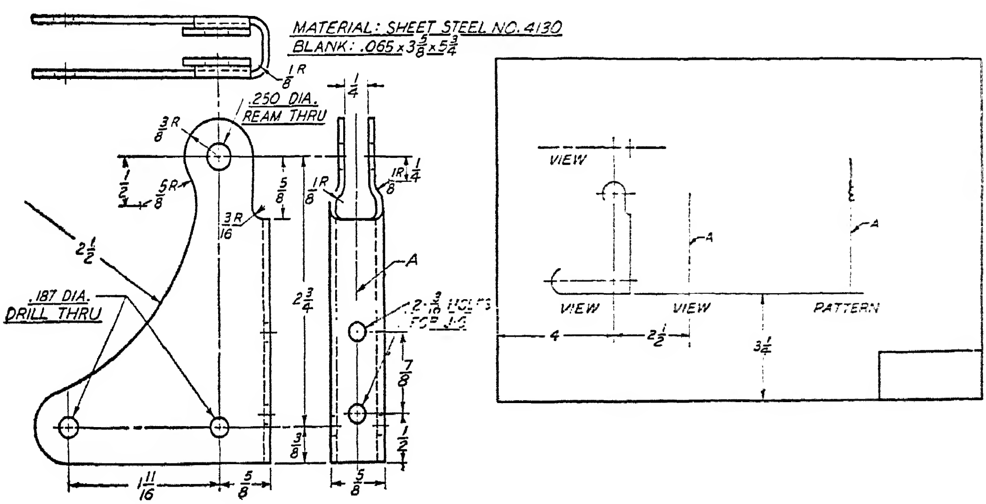


FIG. 13–53. Prob. 13–48. Support.

Prob. 13-50. Fig. 13-54. — Make a drawing of the BRACKET-R.H. Inboard Nac. Sta. 2E. Material: 24SO HT24ST. Use a different arrangement of views. Rear main view is shown, draw a front view. (Boeing Aircraft Company.)

Prob. 13-51. Fig. 13-54. — Lay out flat patterns for the parts shown.

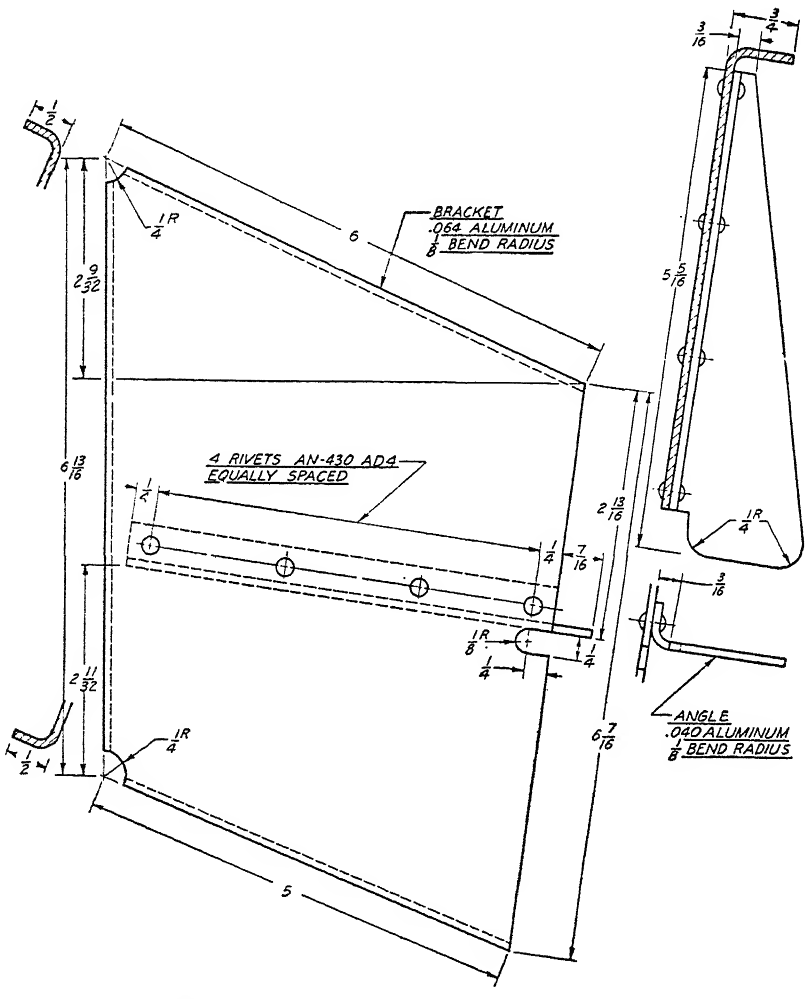


FIG. 13-54. Probs. 13-50 and 13-51. Bracket.

Prob. 13–52. Fig. 13–55. — Make a drawing of the FRONT LANDING GEAR FITTING. Show an auxiliary view in direction of arrow "*A*." Draw flat patterns for sheet metal parts. Refer to Chap. XVII. (Taylor Aircraft Company.)

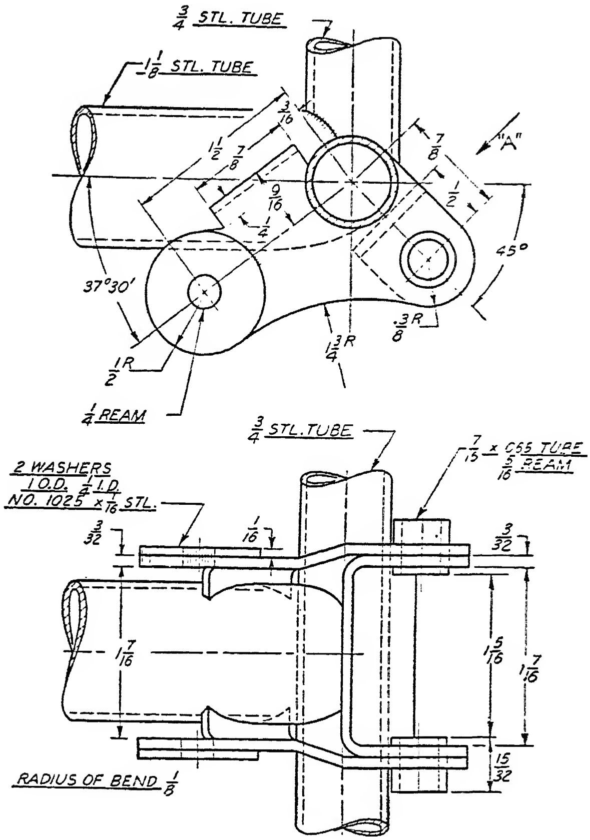


FIG. 13–55. Front Landing Gear Fitting. Prob. 13–52.

Prob. 13-53. Fig. 13-56. — Make a drawing of FRONT LANDING GEAR FITTING AND flat patterns for the sheet metal parts as suggested at –1, –2, and –3 on the sheet layout. Material: 3/32, No. 1025 steel. Welded. (Taylor Aircraft Company.)

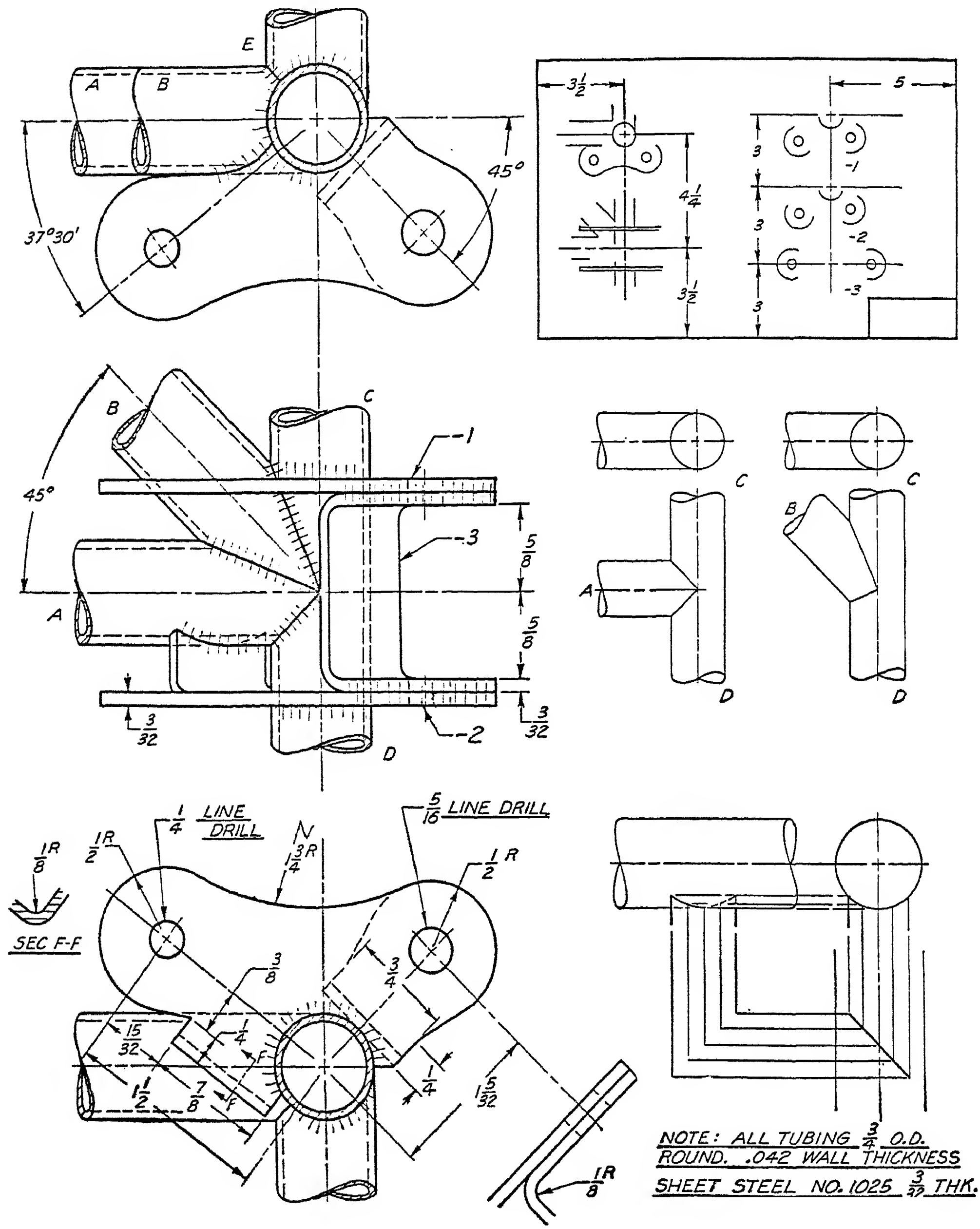


FIG. 13-56. Front Landing Gear Fitting. Prob. 13-53.

Prob. 13-54. Fig. 13-57. — Make a drawing of the FITTING ASSEMBLY and flat patterns as suggested in the layout. Upper view is to be complete. Show welds and add note: "Weld as shown." (Interstate Aircraft and Engineering Corporation.)

Prob. 13-55. Fig. 13-58. — Make a drawing for the FITTING as shown. Use 8½ × 11 sheet. (This is part B 1065 called for in Prob. 13-58.)

Prob. 13-56. Fig. 13-59. — Make a drawing for the CLIPS as shown. Use 8½ × 11 sheet. (This is part B1082 called for in Prob. 13-58.)

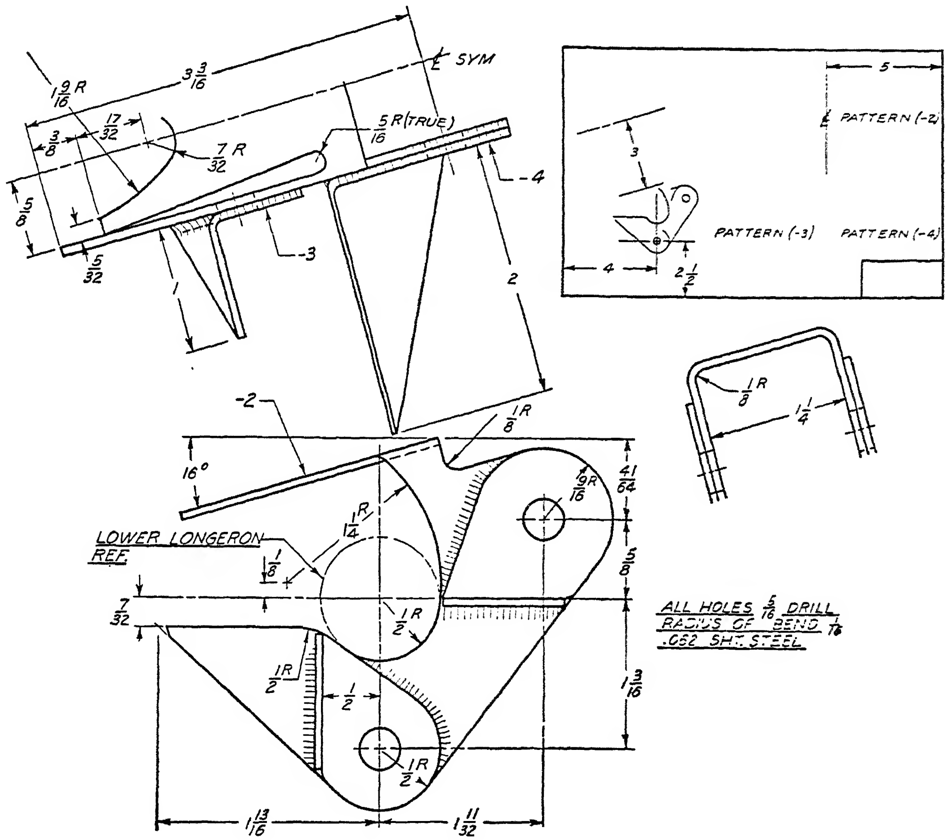
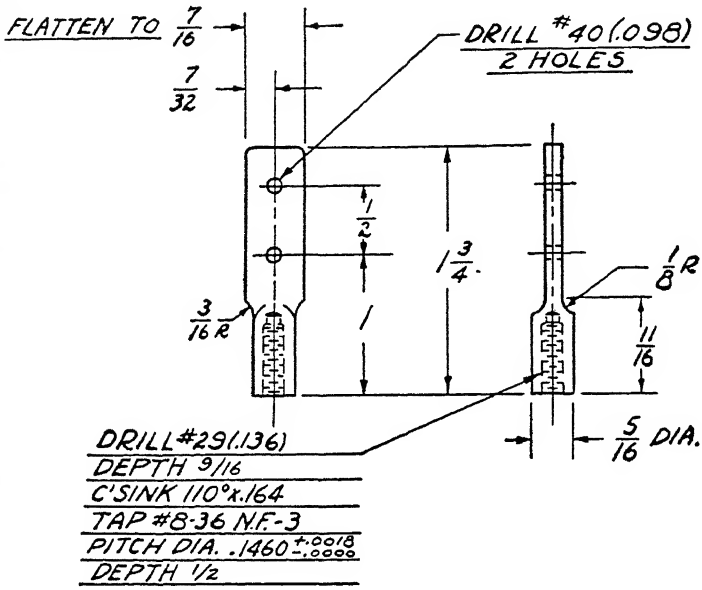


FIG. 13-57. Fitting Assembly. Prob. 13-54.

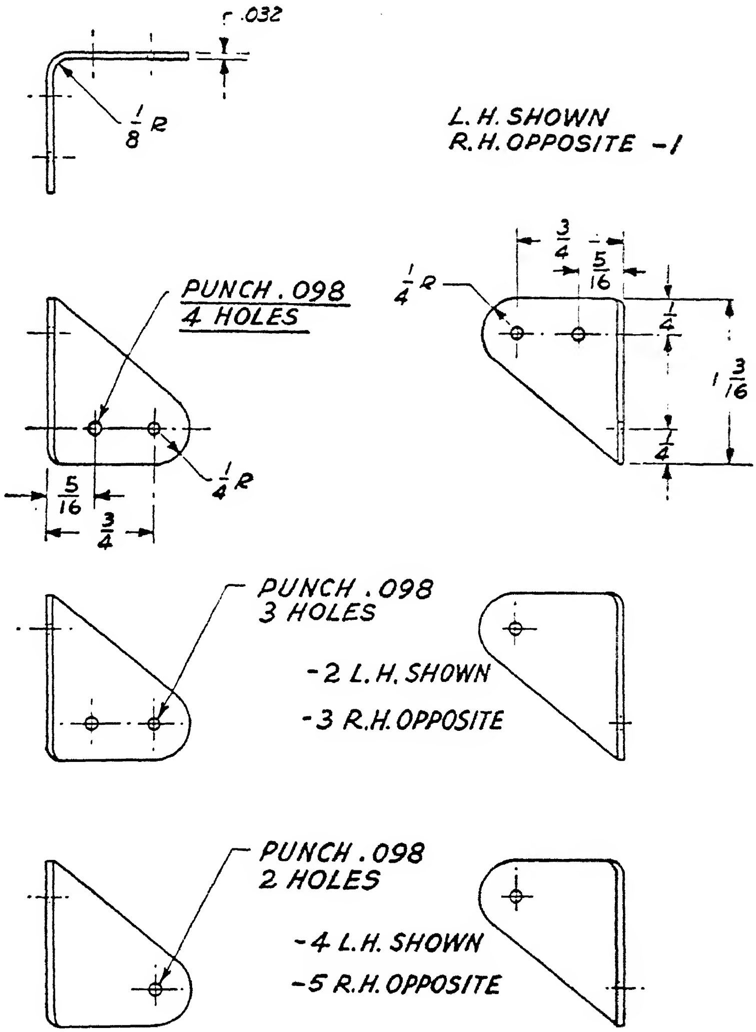


NOTE:- INACTIVE FOR DESIGN BEGINNING ON NA73

HEAT TREAT-A. SPEC. 98-10026

SCALE FULL SIZE	NORTH AMERICAN AVIATION INC.		STANDARD
FINISH ANODIZE	NAVY SPEC.	ARMY SPEC.	MATERIAL
WEIGHT	46 A 9	57-152-5	AL. ALLOY BAR 24SO
CHECKED SIGAFOOSE	FITTING		B1065
APPROVED J.S.S.			

FIG. 13-58. Fitting. Prob. 13-55.



NOTE: DIMENSIONS ARE COMMON TO ALL DASH No 5.

SCALE FULL SIZE	NORTH AMERICAN AVIATION INC.		STANDARD
FINISH ANODIZE AND PRIME	NAVY SPEC.	ARMY SPEC.	MATERIAL
WEIGHT	47A8 COND. T	11067 TYPE II	AL. ALLOY 24 STAL
CHECKED-TORR 6-30-37 APPROVED-SMITHSON	CLIP 1x1		B1082

FIG. 13-59. Clip. Prob. 13-56.

Prob. 13-57. Fig. 13-60. — Make a drawing for the CLIP — Outer, Wing Conduit. Add note: " Make from B1082 (Blank)." See Prob. 13-56. (This is part 19-14095-1 called for in Prob. 13-58.)

Prob. 13-58. Fig. 13-1. — Make a drawing of the OUTER RIB ASSEMBLY, complete as shown. Refer to Art. 13-2. For clips and fitting see Figs. 13-58, 13-59 and 13-60. Refer also to Chapter XVII. (North American Aviation.)

Prob. 13-59. Fig. 13-61. — Make a drawing of the WING RIB, Outer Panel, #2 Nose. (Engineering and Research Corporation.)

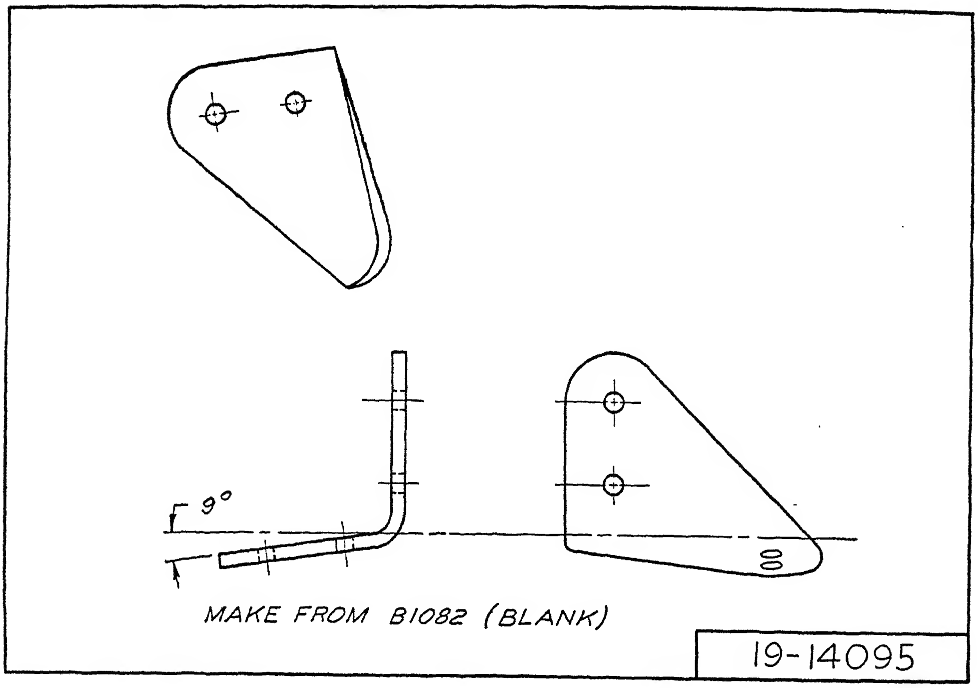
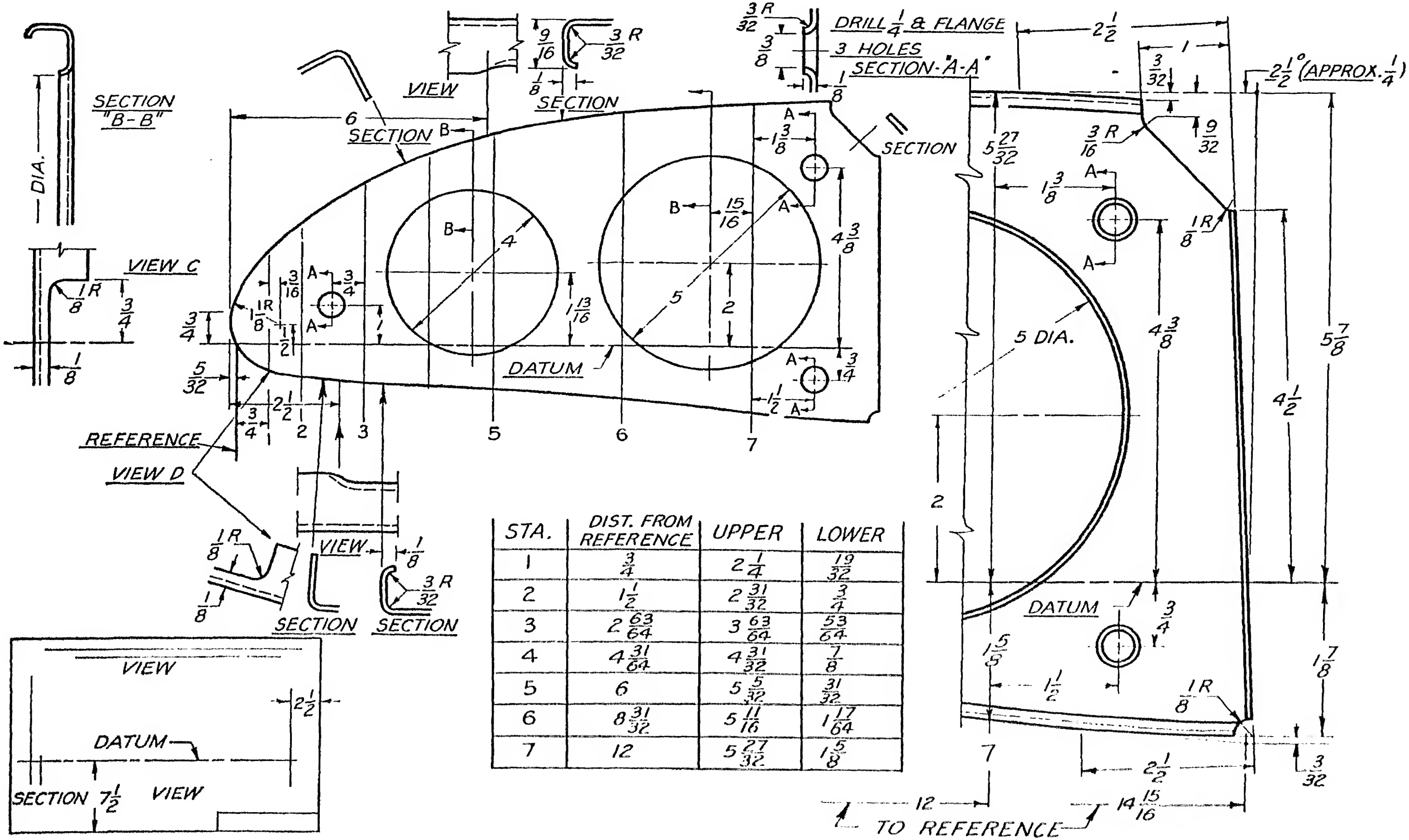


FIG. 13-60. Clip. Prob. 13-57.



STA.	DIST. FROM REFERENCE	UPPER	LOWER
1	$\frac{3}{4}$	$2\frac{1}{4}$	$\frac{19}{32}$
2	$1\frac{1}{2}$	$2\frac{31}{32}$	$\frac{3}{4}$
3	$2\frac{63}{64}$	$3\frac{63}{64}$	$\frac{53}{64}$
4	$4\frac{31}{64}$	$4\frac{31}{32}$	$\frac{7}{8}$
5	6	$5\frac{5}{32}$	$\frac{31}{32}$
6	$8\frac{31}{32}$	$5\frac{11}{16}$	$1\frac{17}{64}$
7	12	$5\frac{27}{32}$	$1\frac{5}{8}$

FIG. 13-61. Rib, Outer Panel. Prob. 13-58.

CHAPTER XIV

AIRCRAFT DRAWINGS

14–1. The principles of drafting as applied to the description of shapes and sizes in accord with aircraft drafting practice have been covered in the preceding chapters. All of this must be considered when making drawings, together with the detailed standard practice and data as contained in the aircraft manufacturers' drafting and engineering manuals, Army and Navy procedure or other necessary requirements.

14–2. Classes of Aircraft Drawings. — A general classification arranges aircraft drawings in groups as: Detail Drawings, Assembly Drawings, Installation Drawings, Layout Drawings, Rework Drawings. These classes may include further sub-divisions or they may represent classes of drawings in certain basic groups as indicated in Art. 14–8.

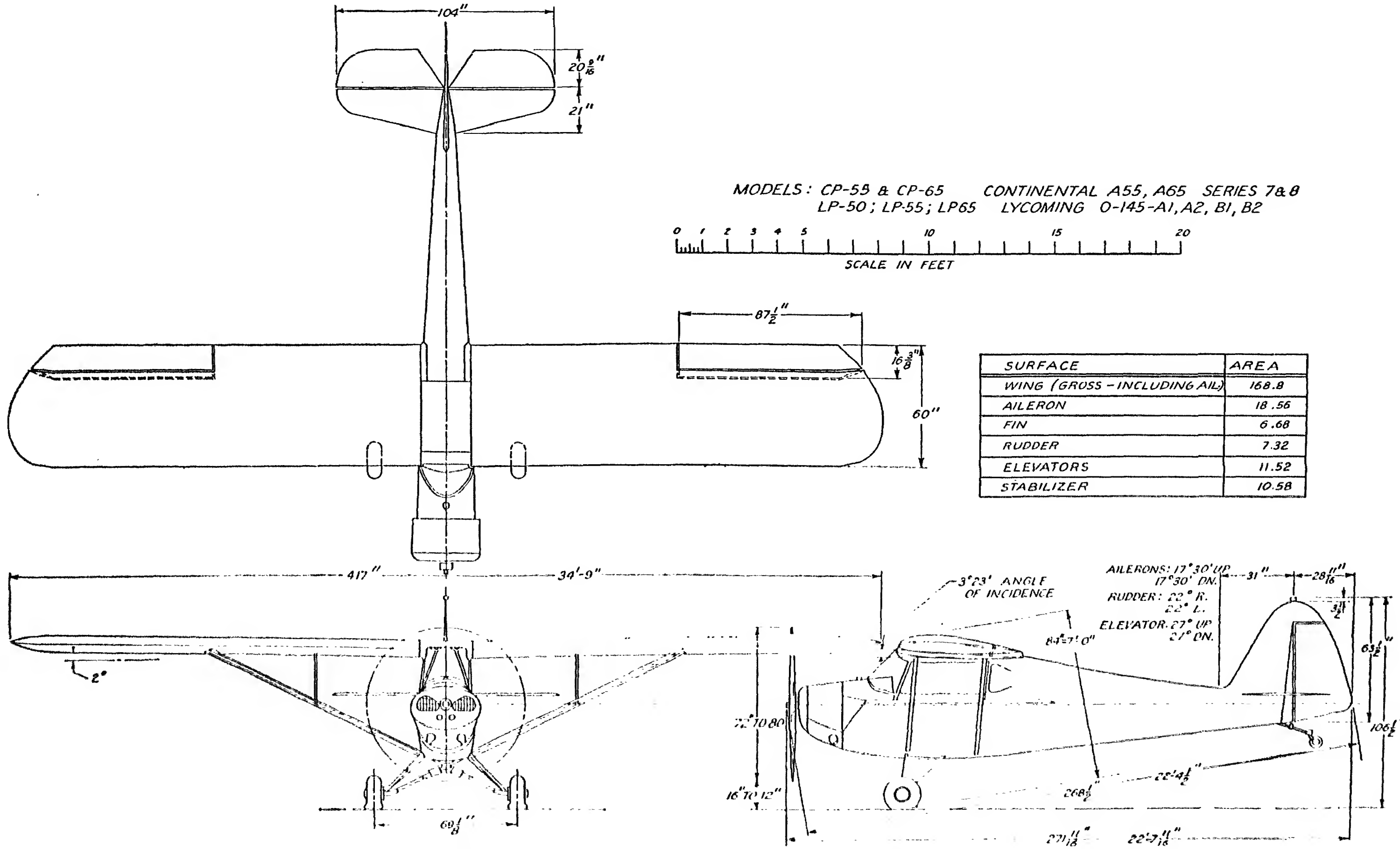
14–3. A detail drawing describes a separate part and gives all the necessary information for making the part. In general, a single sheet is used for each detail or part. Detail drawings are shown in Figs. 7–1 and 12–1 and many other illustrations.

14–4. Assembly drawings give all the necessary information required to join two or more parts. If complete information for fabrication is given they are assembly working drawings, sometimes called assembly details. However, assembly drawings should have the location dimensions, etc., necessary to fix the relationship of the different parts. Assembly drawings may show a few related pieces, a group of parts or parts for a complete unit (sub-assembly), or may include all parts for a major unit as fuselage, wing, landing gear, etc. Assembly drawings are generally made from the details and this makes an accurate check on the dimensioning possible.

The part numbers of sub-assemblies should be given on main assembly drawings but the part numbers which make up the sub-assemblies should not be given.

A three-view outline drawing of a Porterfield Airplane is given in Fig. 14–1. This drawing shows the appearance of the airplane, gives over-all dimensions and certain other dimensions and information. The graphic scale is for problem use and is not a part of the drawing.

14–5. Installation drawings show the method of installing assemblies or details in the airplane or components thereof. They usually show, in phantom, the structure to which the part is fastened, necessary locking dimensions and attaching parts. Location and reference dimensions are important. Part numbers required include the sub-assembly or detail drawings necessary for attaching or putting together but not the numbers of the parts which make up the major or sub-assemblies listed on the installation drawing.



SURFACE	AREA
WING (GROSS - INCLUDING AIL.)	168.8
AILERON	18.56
FIN	6.68
RUDDER	7.32
ELEVATORS	11.52
STABILIZER	10.58

FIG. 14-1. Three-View Assembly Drawing. Prob. 14-1. (*Porterfield Aircraft Corporation.*)

14–6. Layout drawings show the shape or contour, size, and location of some part or group of parts. It is a general drawing which gives the complete and accurate relation of the parts with all necessary tie-in dimensions. If clearances are small, a full size or larger scale should be used. All pertinent data, notes, etc., should be included. All information needed by the detailers for making detail drawings of parts should be given to insure that the parts will fit the completed structure.

14–7. Rework drawings are used to indicate how a part can be worked over so that it can be used to correct or revise parts where necessary, etc.

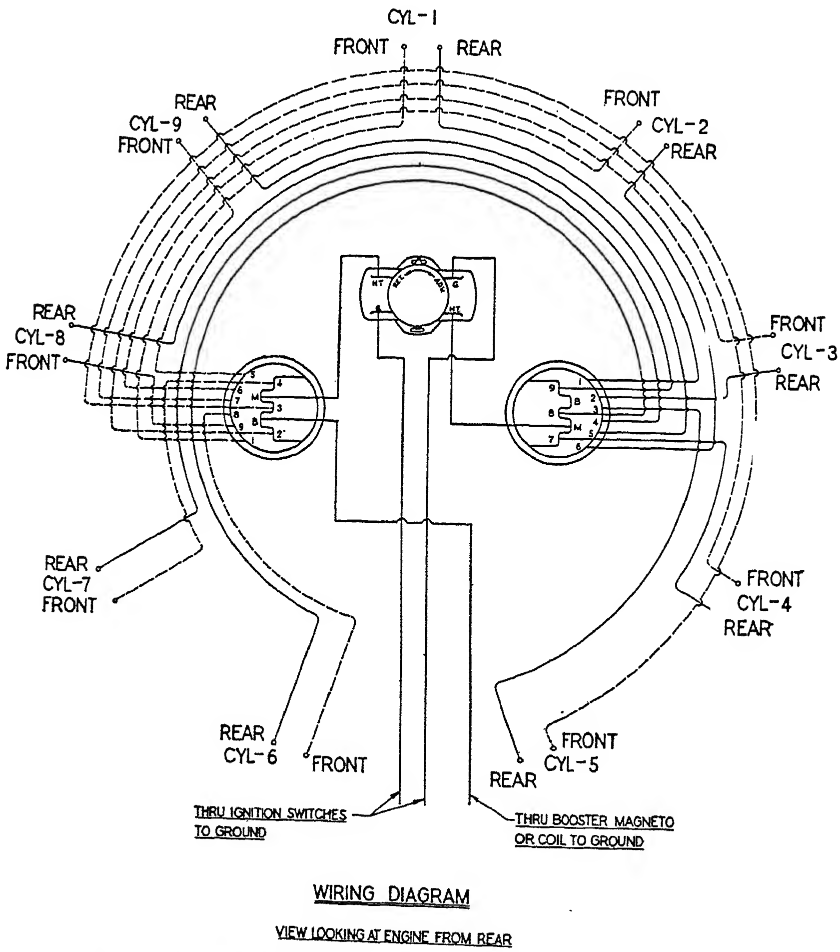


FIG. 14–2. Wiring Diagram. Lycoming Radial Aviation Engine.

14–8. Basic dimension drawings are described in the Lockheed Aircraft Corporation Drafting Manual from which the following is quoted.

"As a basis for basic dimension drawings, each model shall have a three-view basic dimension drawing of the entire airplane. This drawing shall conform to the requirements for major

dimension information as listed in the ' U. S. Army Handbook of Instruction for Airplane Designers.' The three-view basic drawing will also act as an index for all other basic dimension drawings which give basic data about the airplane. Regular production drawings, containing basic data, will be located by following the Lockheed Standard Airplane Breakdown.

" The following list of required basic dimension drawings will vary with each model, but as a general rule will be applicable.

" 1. Three-view drawing of a complete airplane.
" 2. Wing structure.
" 3. Wing tip structure.
" 4. Aileron structure.
" 5. Wing flap structure.
" 6. Stabilizer and elevator structure.
7. Fin and rudder structure.
8. Fuselage structure.
9. Landing gear pin centers diagram.
10. Nacelle structure and engine mount pin centers diagram.
11. Controls and rigging diagram.
12. Flap mechanism diagram."

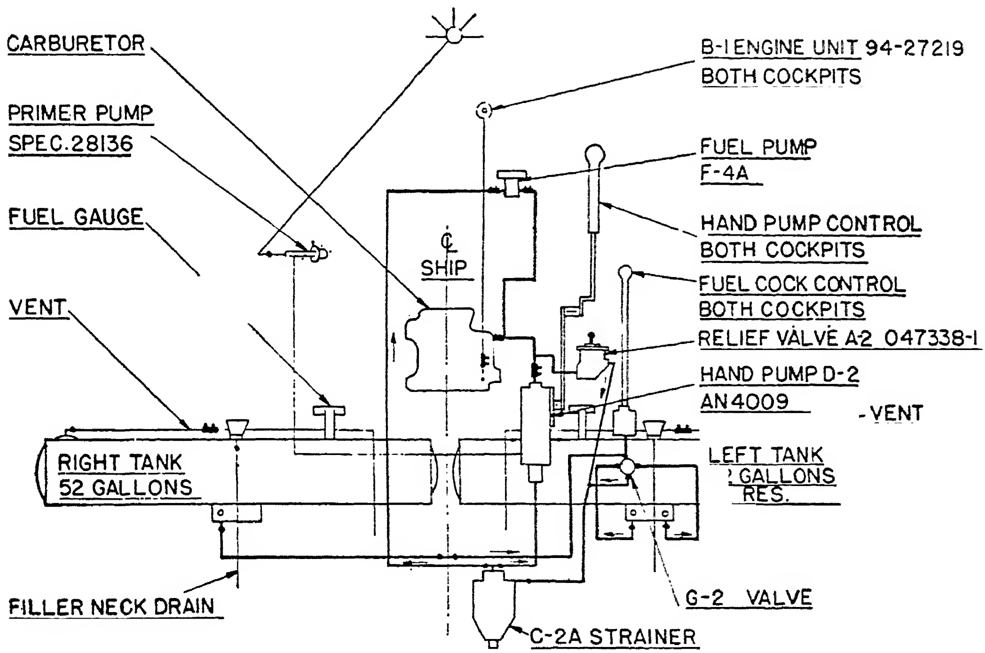


FIG. 14–3. Fuel System Diagram. (*North American Aviation, Inc.*)

14–9. Diagram drawings are made to indicate the arrangement and operation of electric wiring systems, piping systems for fuel, oil and hydraulic operated mechanisms, and for mechanically or otherwise operated control systems.

A wiring diagram for a Lycoming radial aviation engine as made to show the proper method of installing the electrical wiring is illustrated in Fig. 14–2. A fuel system diagram is illustrated in Fig. 14–3 and a control diagram in Fig. 14–4. Note that Fig. 14–4 is a pictorial or " space " diagram. Other control systems may be drawn in a similar manner.

14–10. Drawing and Group Number Chart. — North American Aviation, Inc., classifies drawings in five basic groups as: WING, EMPENNAGE, FUSELAGE, POWER PLANT and FIXED EQUIPMENT.

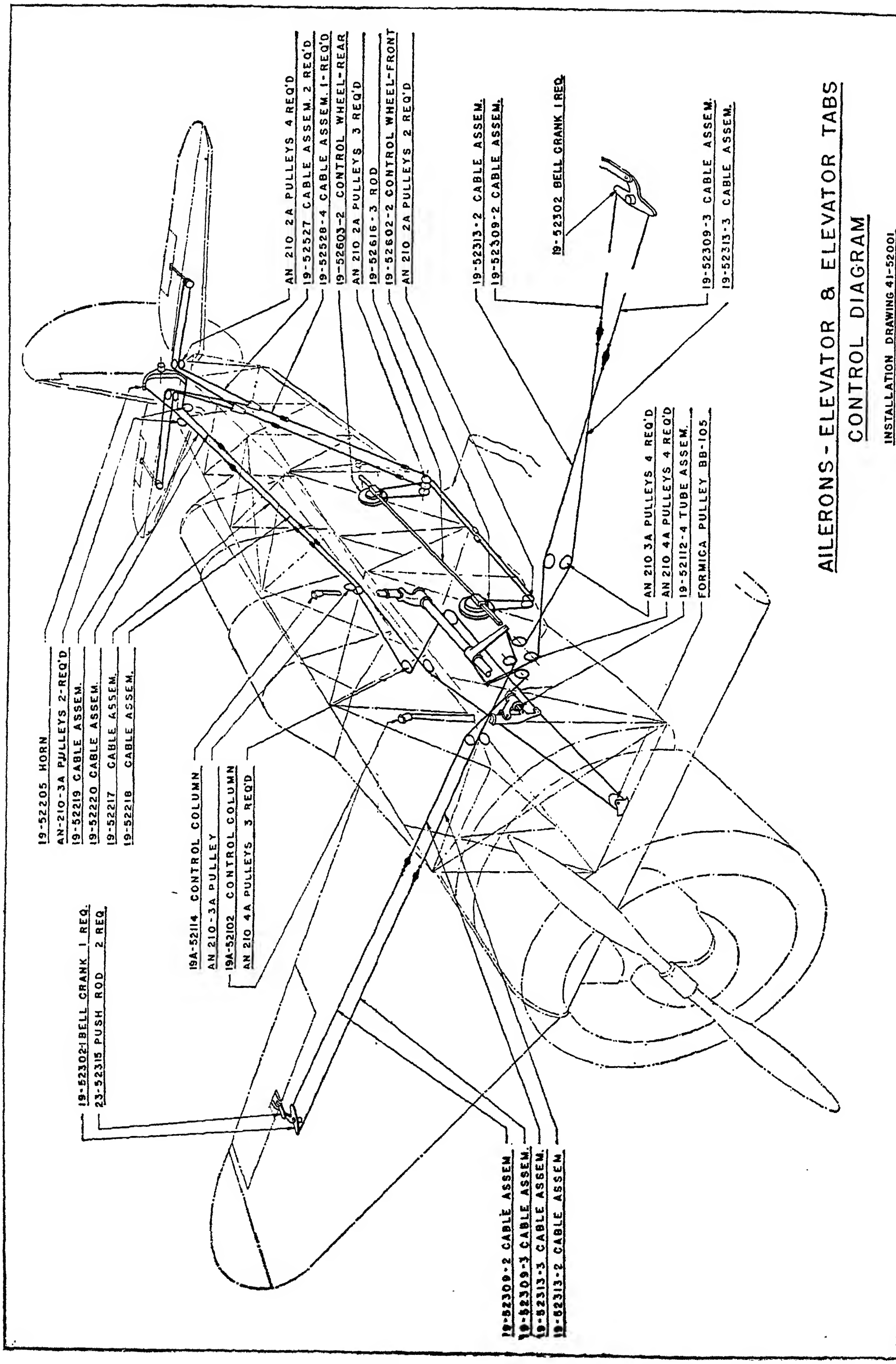


FIG. 14-4. Schematic Control Diagram. (*North American Aviation, Inc.*)

"These five main groups are divided into several supporting sub-groups. The drawing (Fig. 14–5) and drawing and group number chart (Fig. 14–6) illustrate the basic numbers assigned to the five main and sub-groups.

"When assigning numbers to a drawing an attempt is made to correlate the numbers, so as to standardize the number that a given part is to receive regardless of what airplane the part is used on. The numbers used on any drawing are identified for one particular model by prefixing the model number and separating this number from the basic drawing number by a dash as (55–48001).

"There are occasions when standard production numbers, as outlined above, are not applicable to a given drawing. In the majority of cases this will occur previous to the actual release of an airplane. The types of drawings which do not carry production numbers may be noted at the top of the drawing and group number chart."

14–11. Notes on drawings are necessary to give information which cannot be shown as readily by dimensions or symbols, such as machining or other operations, to avoid crowding on complicated views, special instructions and "call out" notes.

Certain "operation" notes as for drilling, reaming, spotfacing, etc., generally include such dimensions as diameter, depth, etc. Numbers and quantities should be given where necessary. In general, notes should read parallel to the title, but they may be placed in a vertical direction if necessary for clarity. Leaders or arrow lines should be used as explained in Chapter XI.

Notes should be very carefully worded to have only one meaning. Unnecessary words should be avoided. Notes for the same purpose should be worded in the same way and company practice ascertained and followed. Examples of notes for various purposes are shown on the illustrations throughout this book.

14–12. Bill of Material. — A bill of material having no detailed sub-assemblies is illustrated in Fig. 14–7. Bills of material will vary according to the type of drawing as on assemblies with sub-assemblies, design assembly drawings, installation drawings, etc. Most companies have a standard procedure which must be followed. The purpose of a bill of material is to furnish all necessary information in convenient form to order and fabricate the parts. It is, therefore, very important to be certain that all parts called for on the face of the drawing are properly listed. The numbers on Fig. 14–7 are explained in connection with this bill of material as follows:

(1) Even dash numbers shall be called for as left-hand parts and odd dash numbers as right-hand parts, when right- and left-hand assemblies are involved.

(2) Parts are to maintain numerical order within the group. The following sequence is to be adhered to.

1 Drawing dash numbers
2 Company parts same model
3 Company parts other models
4 B. & C. standards
5 Commercial Parts
6 Army, Navy, Major standards
7 A.N. Book & N.A.F. standards

(3) Insert company finish specification in these columns.

(4) To be filled in by the draftsman only for the model the drawing was originated for. Additional requirements for other models established in the Drawing Records Group by the Advance Release System, will be added by the Drawing Records Group.

(5) The dash 1 may be used only for R.H. parts or assemblies.

(6) This column is to indicate the number per airplane.

(7) No purchased parts, such as springs, name plates, & phenol fiber parts, shall be detailed on this drawing.

⑧Only such parts that are completely detailed on this drawing will have the size, material, and finish specification columns filled in. No stock size, material or finish specification is necessary when calling for a foreign or commercial part.

⑨When left-hand and right-hand parts are used respectively on the left and right assemblies, they are to be called out on one line.

⑩The number required for assemblies never changes, it always is one.

⑪This column is to be used when the assembly is neither left- nor right-hand. The R.H. assembly column is to remain blank.

⑫Provide for additions by reserving blank spaces between groups.

14–13. Lofting. — The following excerpts on lofting are quoted from the Curtiss Engineering Manual by courtesy of Curtiss Aeroplane Division, Curtiss-Wright Corporation.

"The Mold Loft is a division of the Engineering Department. It has three functions — first, the development of all lines; second, the fabrication of templets for shop use; and third, the check and correction of such engineering drawings as involve Mold Loft work. The manner in which the loft operates is outlined in this section.

"The loft 'lays down' all lines, full size, of fuselage, panel, tail assembly, float, etc., from engineering information. These lines are 'faired up' to the engineers' satisfaction.

"This fairing process is done on the loft floor using spruce battens. The floor is of 1½″ white wood on 2″ fir sub-floor. It is accurately leveled at the time of installation. A base board is spiked down at either side of the floor, set as close as possible with a piano wire. With this straight base board as a starting point, the floor is divided into 4 foot squares, at the corner of which are set brass escutcheon pins. These squares, set with calibrated tape and spring balance, make long measurements, with attending possibility of error, unnecessary.

"As a product of these fairing operations, a body plan is made of the various structures. This is a cross-section view of all frames, nested, and cut into birch ply-wood or scribed on sheet metal. From these body plans the shape of all frames, bulkheads, ribs, etc., is obtained without further layout.

"The templets to be made in the Mold Loft for Shop use should fall into one of five divisions:

"A. Contour ....designated T-1
"B. Marking..............designated T-2
"C. Apply ....designated T-3
"D. Drill Jig ....designated T-4
"E. Form Block ....designated T-5
"F. Routing ....designated T-6

"All metal templets are made of galvanized sheeting painted on one side with red primer. The templets are used with the painted side, which also contains the stamping up, so that the *unpainted* side always contacts the subject. Obviously, when making lefts and rights from one templet, this does not hold true; but in such a case, the templet is painted to agree with the hand shown on the engineering drawing.

"*Contour Templet — Type T-1* (Fig. 14–8): This templet is one made to inside of skin, or mold line, or in general to the heel of the structural member. It is used for providing shape for marking form blocks, dies, etc. When using for that purpose the form maker will have to deduct thickness of metal. This templet contains only form holes that match the marking templet and the bevels stamped near the edge.

"*Marking Templet — Type T-2* (Fig. 14–9): This templet is used for marking and drilling or perforating of sheet stock. It is made of .065″ sheet although heavier metal may be requested where the templet itself is used for a drill jig with full sized holes.

"*Apply Templet — Type T-3* (Fig. 14–10): This templet is applied directly to the formed part. It is usually made of .065″ sheet and may be in angle, channel or any other form. It is the templet called for to drill holes in a part which has to be welded and is used after welding and heat treating.

"*Drill Jig Templet — Type T-4* (Fig. 14–11): This templet is made for the express purpose of spacing and arranging holes in a drilling fixture. It is made of .065″ sheet.

"*Form Block Templet — Type T*-5 (Fig 14-12): This type of templet is made of .040″ sheet. They are cut to the inside of metal, i.e., to the mold line *less* thickness of metal, thus providing the neat line of form block.

"*Routing Templet — Type T*-6 (Not illustrated): The templet is made of .065″ galvanized sheet fastened with c'sunk head wood screws to a piece of ½″ fir plywood cut to the identical size of the templet. The outline of the templet is 3/16″ back from the edge of the finished part or Marking Templet due to the difference in diameter between the router guide and router cutter."

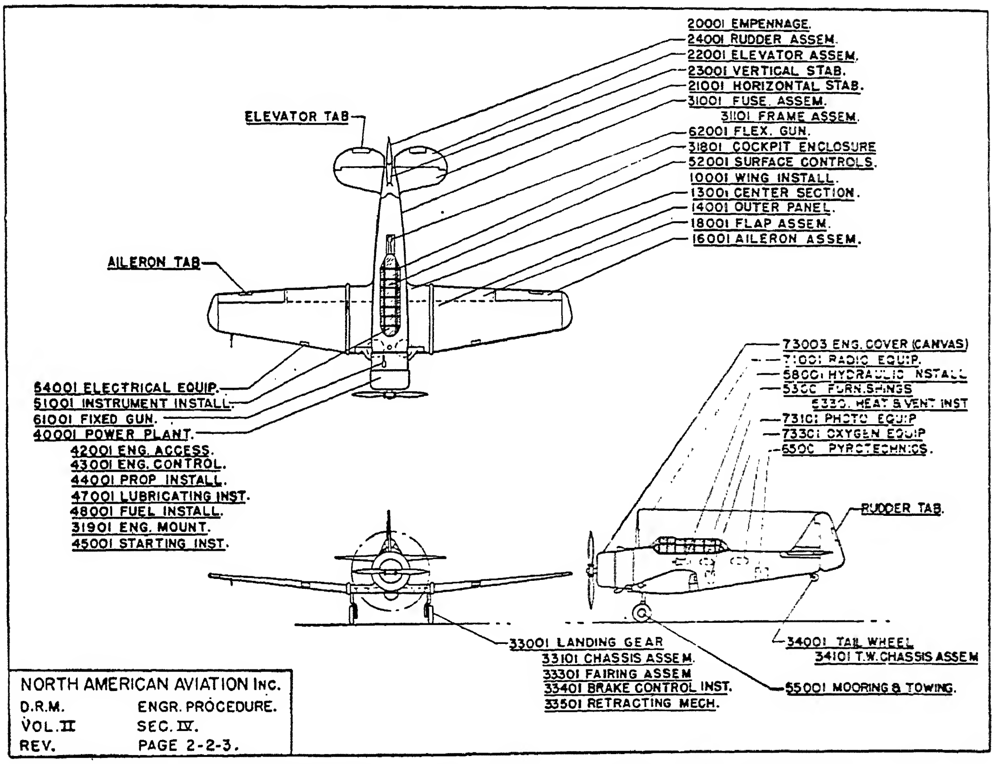


FIG. 14-5. Group Names and Numbers. (*North American Aviation, Inc.*)

14-14. Checking Drawings. — The purpose of checking is to insure correct drawings. Specially trained checkers are employed in large drafting rooms for this important work. The purpose, design, dimensioning, representation, conformity with company practice, etc., must be considered when checking a drawing.

A CHECK LIST

1. *References.* — The checker should have available all other drawings used as references, and all notes, sketches, reports, computations, catalogs, standard parts and specifications, books of company practice, Army and Navy Standards, Air Corps Standards, and any other information needed.

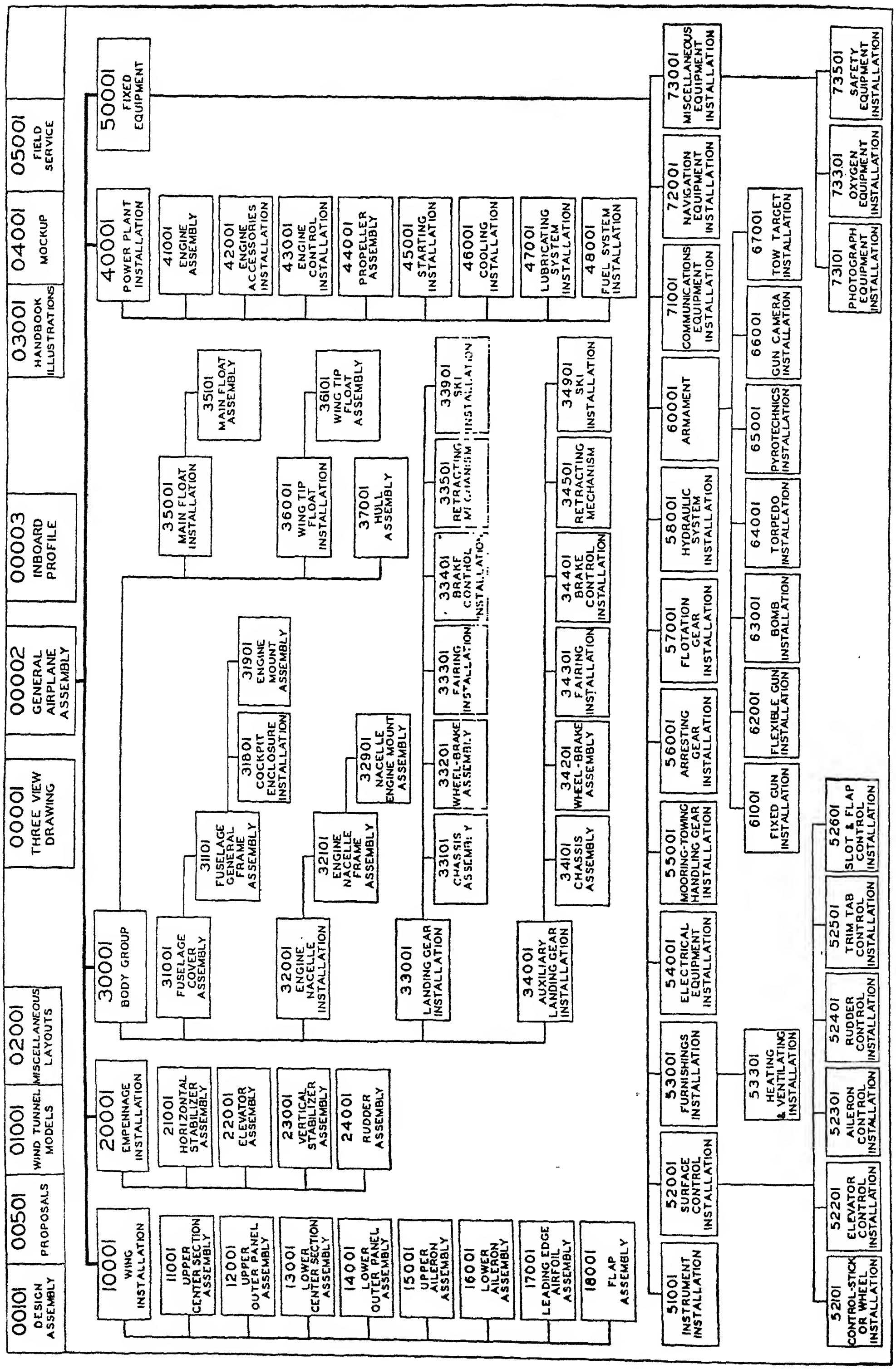


FIG. 14-6. Drawing and Group Number Chart. (*North American Aviation, Inc.*)

2. *Design Features.* — The parts must be checked for suitability of material, strength and proportions, practical limits for proper functioning, operation and assembly, clearances, interferences, general agreement with previous practice, and ease and accessibility of assembly and replacement.

PART NO (R H ASSEM)	NO REQ	PART NO (L H ASSEM)	NO REQ	DESCRIPTION (MATERIAL)	SIZE (MATERIAL)	ZONE	ARMY (MATERIAL SPEC.)	NAVY (MATERIAL SPEC.)	ARMY (FINISH SPEC.)	NAVY (FINISH SPEC.)	NO REQ. SHIP	NEXT ASSEM.	MODEL
AC531-8-6	8			SCREW		5							
AC531-6-6	1	AC531-6-6	1	SCREW		3							
AC530-4-4	2	AC530-4-4	2	SCREW		5							
AC525-10-32	1	AC525-10-32	1	SCREW		4							
AC525-10-28	1	AC525-10-28	1	SCREW		4							
AC525-10-22	1	AC525-10-22	1	SCREW		4							
AC525-10-20	2	AC525-10-20	2	SCREW		4							
AC525-10-14	3	AC525-10-14	3	SCREW		4							
AC365-1032	8	AC365-1032	8	NUT		4							
B1221D	1	B1221D	1	PLATE		5							
49-17007-1	1	49-17007	1	BRACKET		5							
49-17004-1	1	49-17004	1	CASTING		5							
49-17003-1	1	49-17003	1	CASTING		3							
49-17002-1	1	49-17002	1	CASTING		2							
19-17008	1			CASTING		6							
36-17006-9	1	36-17006-8	1	BRACKET		3							
36-17006-3	1	36-17006-2	1	ANGLE ASSEM.		3							
36-17005-1	1	36-17005	1	BRACKET		2							
-5	1	-4	1	ALCLAD SHT. 24ST	.051 x 9 x 64	3	11067						
-3	1	-2	1	ALCLAD SHT. 24ST	.051 x 10 x 64	3	11067				1 R.H.	36-17000-1	BC-1
36-17001-1	1	36-17001	1	ASSEMBLY					FA-25		1 L.H.	36-17000	BC-1

ACT WT / CAL WT / HEAT TREAT	∫ 3 SMOOTH MACH. FINISH ∫ 5 RG. FILE OR GRIND LIMITS EXCEPT AS NOTED: ANGLE ± ½°, FRACTIONS ± 1/64, DECIMAL ± .010 DWG SIZE G	DRAFTSMAN CHECKER APPROVED: N.A.A., ARMY, NAVY DWG. SCALE	NORTH AMERICAN AVIATION, INC. INGLEWOOD, CALIFORNIA SLAT ASSEM.-WING LEADING EDGE	[redacted] 36-17001

FIG. 14–7. A Bill of Material. (*North American Aviation, Inc.*)

3. *Choice of Views.* — Views should be checked for number required to show the parts clearly and correctly. The drawing should be "easy to read." This involves types of views — full, sectional, auxiliary, enlarged, etc., and the correct arrangement of the views. The scale should be checked. The character of line work, contrast, etc., should be checked to insure good reproduction qualities.

4. *Production of Part.* — The method of producing the part involves such processes as pattern-making, die-making, molding, casting, forging, welding, brazing, soldering, riveting, etc. Economical and purpose considerations govern the choice which must be checked. Consider the machines and equipment available.

5. *Dimensioning.* — Each view should be checked for complete and proper dimensions. Are all dimensions correct and "to scale"? Have the needs of different departments such as pattern, foundry, forge, machine, and sheet-metal shops been met by suitable dimensions? Size, location, assembly and installation dimensions must be checked for accuracy, including computations for such

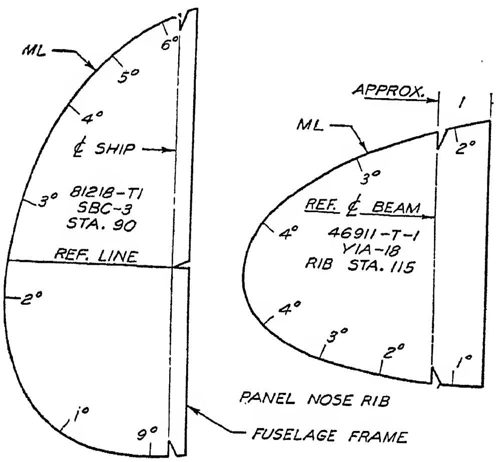


Fig. 14–8. Contour Templets.

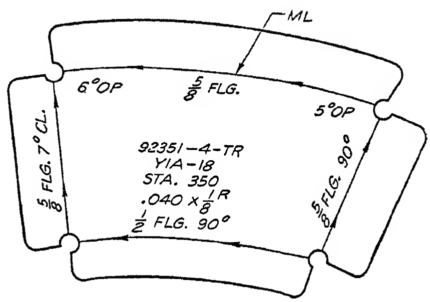


Fig. 14–9. Marking Templets.

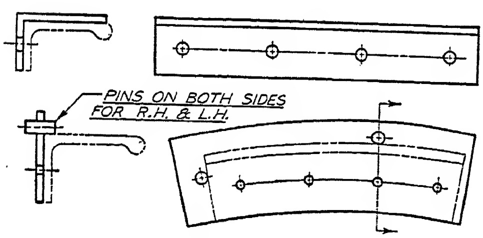


Fig. 14–10. Apply Templets.

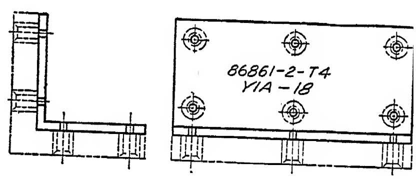


Fig. 14–11. Jig Templets.

dimensions as are affected by mating parts, and strength calculations. Limits, tolerance, and allowance are especially important as well as selection of proper fits. Check for unnecessary, repeated, out of scale, and omitted dimensions.

6. *Machining Operations.* — Check for drilling, reaming, boring, tapping, filing, grinding, lapping, honing, etc., also kinds and quality of finished surfaces. Check finish marks.

7. *Notes, Titles, etc.* — All notes should be checked for clearness and location, bill of material for completeness in all details, and title for proper naming of parts, scale, date, reference, initials of draftsman, etc. Leaders should be used where necessary. Notes should include protective finish, methods of assembling,

structural data, heat treatment, material, hardness, etc., and specification notes for tapped holes, screw threads, keys and keyways, splines, countersinks, counterbores, bosses, and other details.

8. *Standard Parts.* — Bolts, screws, keys, pins, ball bearings, and other standard parts should be checked for conformity with Standard parts — AN, AC, company standards, etc., correct part numbers and suitability for purpose selected.

9. *Miscellaneous.* — Numerous items might be listed under this heading including checking of change slips, elimination of superseded drawings, general features, accessories, special location and operation dimensions for wires, struts, linkages, attached parts, attachments, size of sheet, signatures, and special dimensions and notes for forgings, castings, etc.

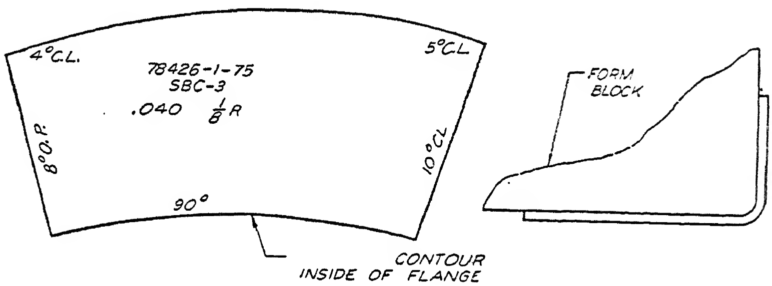


Fig. 14–12. Form Block Templet.

10. *Final Survey.* — The checker should give the drawing a final survey to see that every dimension, note, reference, etc., has been checked and that all errors and changes are noted.

14–15. PROBLEMS. — The problems which follow are to be considered as suggestions. The material presented can be worked up in a number of ways. Some information and data are to be supplied by the student in working up the views from reference to other parts of this book, and to other sources of information.

Prob. 14–1. Fig. 14–1. — Make a three-view drawing of the Porterfield Monoplane. Use the graphic scale. (Porterfield Aircraft Corporation.)

Prob. 14–2. Fig. 14–13. — Make a three-view drawing of the ERCOUPE AIRPLANE. (See Fig. 12–6 for Photograph.) Use graphic scale. Place views in orthographic projection. (Engineering and Research Corporation.)

Prob. 14–3. Fig. 12–10. — Make a three-view drawing of the VOUGHT CORSAIR. Draw a complete top view and place side view in orthographic projection. Omit sections *A–A* to *E–E* inclusive. Use the graphic scale. (Vought-Sikorsky Aircraft.)

Prob. 14–4. Fig. 14–14. — Make a drawing of the WING RIB. (Bellanca Aircraft Corporation.)

Prob. 14–5. Fig. 7–1. — Make a drawing of the VALVE SUPPORT. Consider possible variation in choice and treatment of views, part views, etc. (North American Aviation.)

Prob. 14–6. Fig. 14–15. — Make a drawing of the ELEVATOR ASSEMBLY — Right-hand. Rearrange views. Use graphic scales where necessary. (Interstate Aircraft and Engineering Corporation.)

Prob. 14–7. Fig. 14–16. — Make a drawing of the RUDDER ASSEMBLY from the views and information shown. Other dimensions, etc., to be worked up as the drawing is made. (Bellanca Aircraft Corporation.)

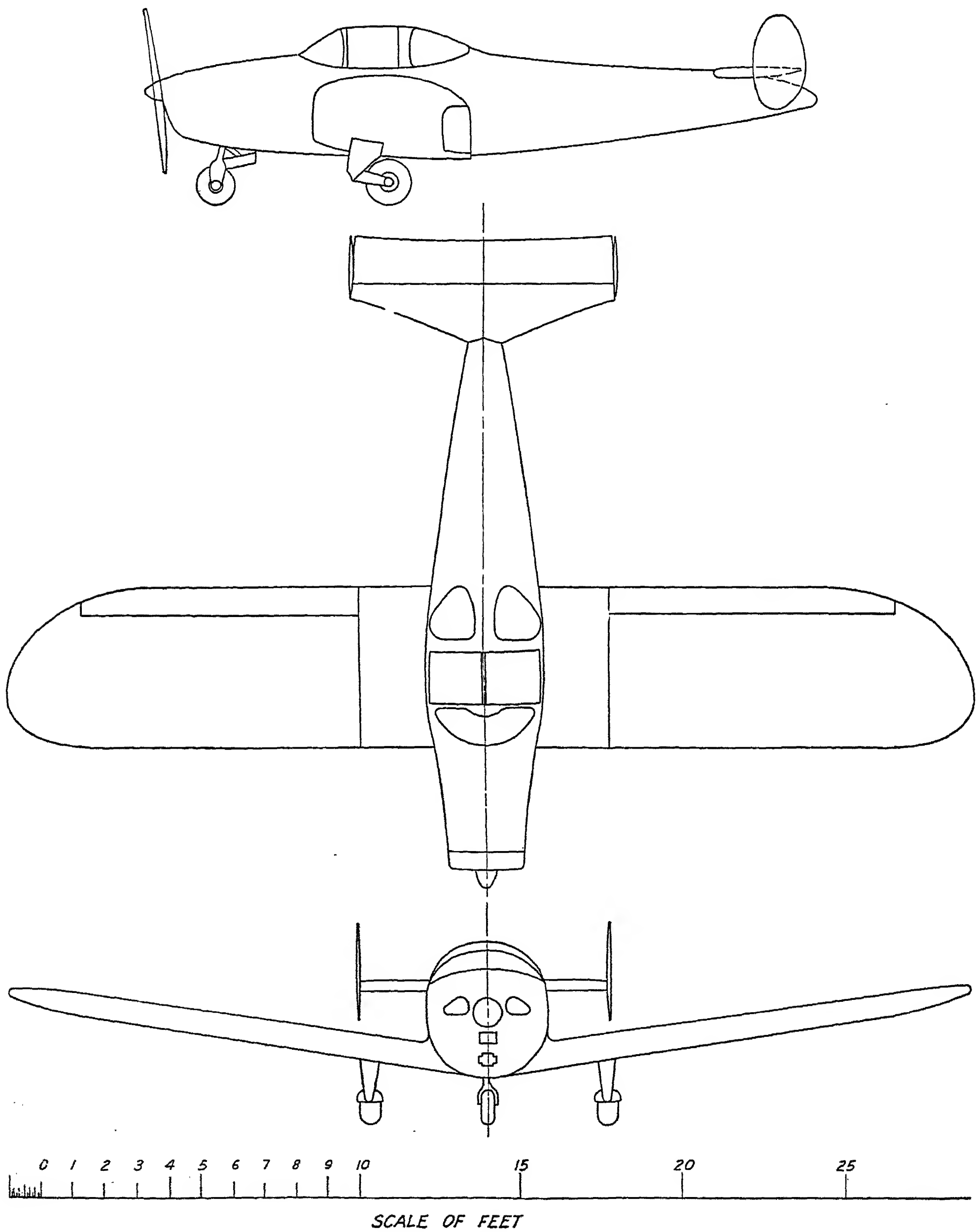


Fig. 14–13. Ercoupe Airplane. Prob. 14–2.

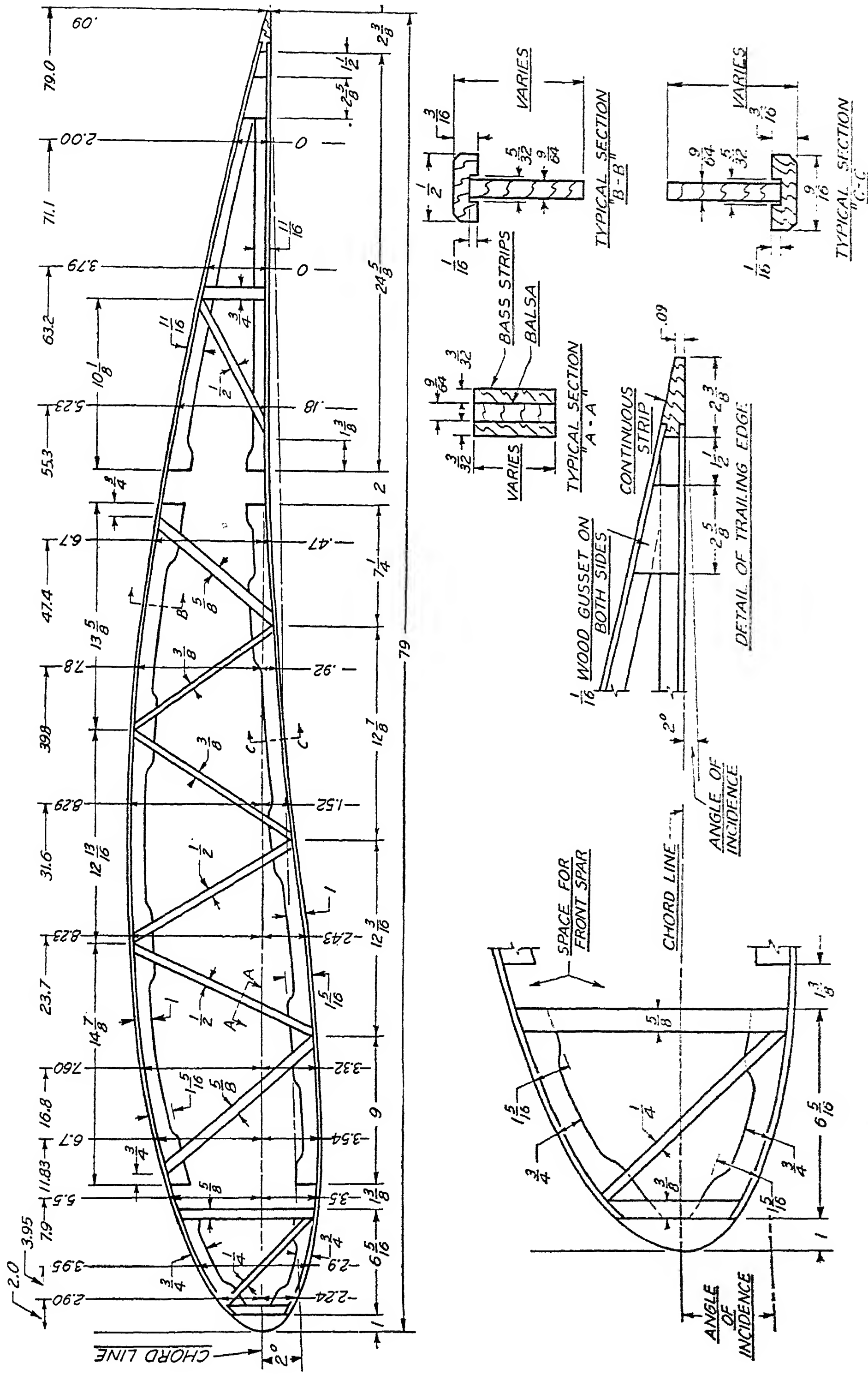


FIG. 14-14. Wing Rib. Prob. 14-4.

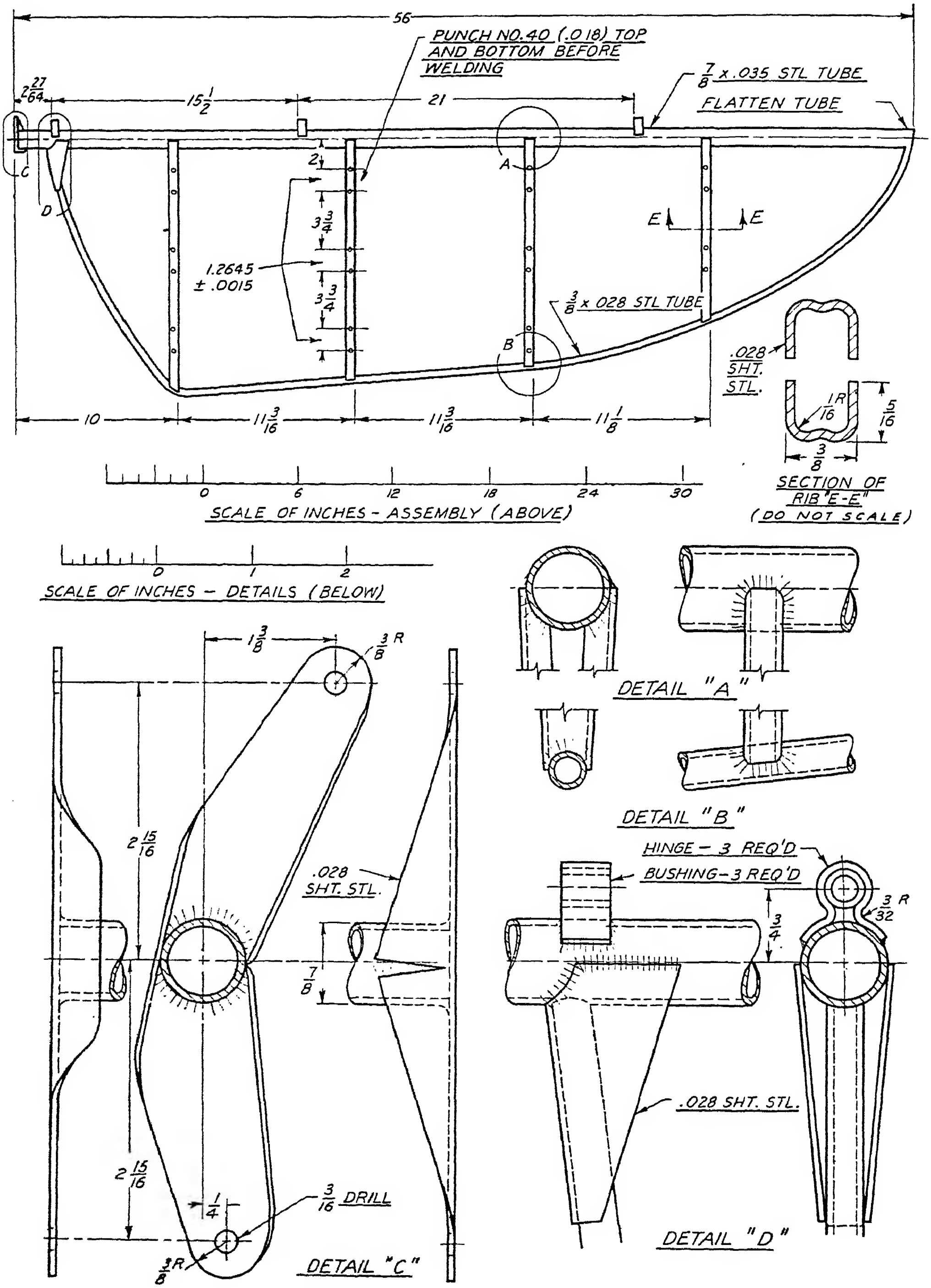


FIG. 14–15. Elevator Assembly. Prob. 14–6.

Prob. 14–8. Fig. 14–17. — Make a drawing of the FORK, Nose wheel. Show sections where indicated. Radii for sections, B, C, D, E and F are $4\frac{3}{16}$ and $3\frac{3}{16}$. Draw a complete sectional view at A–A. Casting, Aluminum alloy 220-T4. (Engineering and Research Corporation.)

Prob. 14–9. Fig. 14–18. — Make a drawing of the FUEL TANK, based upon the illustration. Include three complete views and necessary part views. Ellipse may be drawn by method of Fig. 3–46. (Piper Aircraft Corporation.)

Probs. 14–10 to 14–26. Figs. 14–19 and 14–20 show the details and assembly for a LANDING GEAR SHOCK ABSORBER made by the Interstate Aircraft and Engineering Corporation, El Segundo, California. See also Fig. 12–25.

Probs. 14–10 to 14–15. Fig. 14–19.— Make detail drawings of the parts. Show complete views. Use full views, sections, and half sections to give a clear description of the part. Prob. 14–10, PISTON ROD, B–5027. Prob. 14–11, PISTON, A–5026. Prob. 14–12, PACKING NUT, A–5016. Prob. 14–13, END PACKING RING, A–5030. Prob. 14–14, INTERMEDIATE PACKING RING, A–5031. Prob. 14–15, PACKING RETAINER NUT, A–5015.

Prob. 14–16. Fig. 14–19. — Make a PISTON ROD UNIT ASSEMBLY DRAWING of the details of Fig. 14–19 to show how they go together. Half section and half exterior view. No dimensions. Put on numbers and names of the parts.

Probs. 14–17 to 14–23. Fig. 14–20. — Make drawings for the parts. Show complete views. Use full views, sections, and half sections as required to give a clear description. Prob. 14–17, GASKET, A–5052. Prob. 14–18, ADAPTER, A–5011. Prob. 14–19, OLEO FORK, A–5017. Prob. 14–20, REST, A–5033. Prob. 14–21, SUPPORT, A–5108. Prob. 14–22, GUARD, B–5105. Prob. 14–23, SPRING, A–5029, give description as shown, without views.

Prob. 14–24. Fig. 14–20. — Make a two-view drawing of the CYLINDER, B–5106. Show two complete views, one exterior and one section.

Prob. 14–25. — Make a one-view drawing of the LANDING GEAR SHOCK ABSORBER UNIT ASSEMBLY as shown at the left-hand side of Fig. 14–19.

Prob. 14–26. — Same as Prob. 14–25 but in section.

Probs. 14–27 to 14–42. Figs. 14–21 to 14–23 show the details and assembly for a HYDRAULIC FLAP OPERATING CYLINDER made by North American Aviation, Inc., Inglewood, California.

Probs. 14–27 to 14–38. Fig. 14–21. — Make detail drawings of the parts. Show complete views and use enlarged scale where necessary. Use full views, sections, and half sections as may be necessary to give a clear description. Prob. 14–27, PISTON ROD-RIGHT, 38–58067. Prob. 14–28, PISTON, 25–58031. Prob. 14–29, PISTON ROD-LEFT, 36–58035. Prob. 14–30, SNAP RING, 25–58156. Prob. 14–31, CUP RETAINER, 25–58033 or 25–58034. Prob. 14–32, CUP RETAINER, 36–58032. Prob. 14–33, MOLDED CUP, B–1167. Prob. 14–34, INNER BEARING, 25–58030. Prob. 14–35, SPRING WASHER, 25–58107. Prob. 14–36, SEAL GASKET, 25–58071. Prob. 14–37, PISTON ROD WASHER, 25–58045. Prob. 14–38, STOP COLLAR, 36–58033.

Prob. 14–39. Fig. 14–21. — Make a PISTON ASSEMBLY DRAWING — RIGHT. Parts 36–58067, 25–58031, and one rivet. Add note "Drill #30 (.128) through C' sink 78°× $\frac{7}{32}$ Dia. both ends. AN425AD4-16 Rivet. 1 Req. Grind flush as shown." Put on dimension of $\frac{15}{32}$ to locate center line of rivet from end of rod. (See Fig. 14–23.) Omit other dimensions. Show piston rod and engagement of piston in section.

Probs. 14–40 and 14–41. Fig. 14–22. — Make detail drawings. Show complete views and consider choice and treatment of views. Prob. 14–40, OUTER BEARING, 25–58029. Prob. 14–41, CYLINDER, 36–58031.

Prob. 14–42. Figs. 14–21 to 14–23. — Make a one-view assembly drawing of the HYDRAULIC FLAP OPERATING CYLINDER as shown in Fig. 14–23, including the notes, etc.

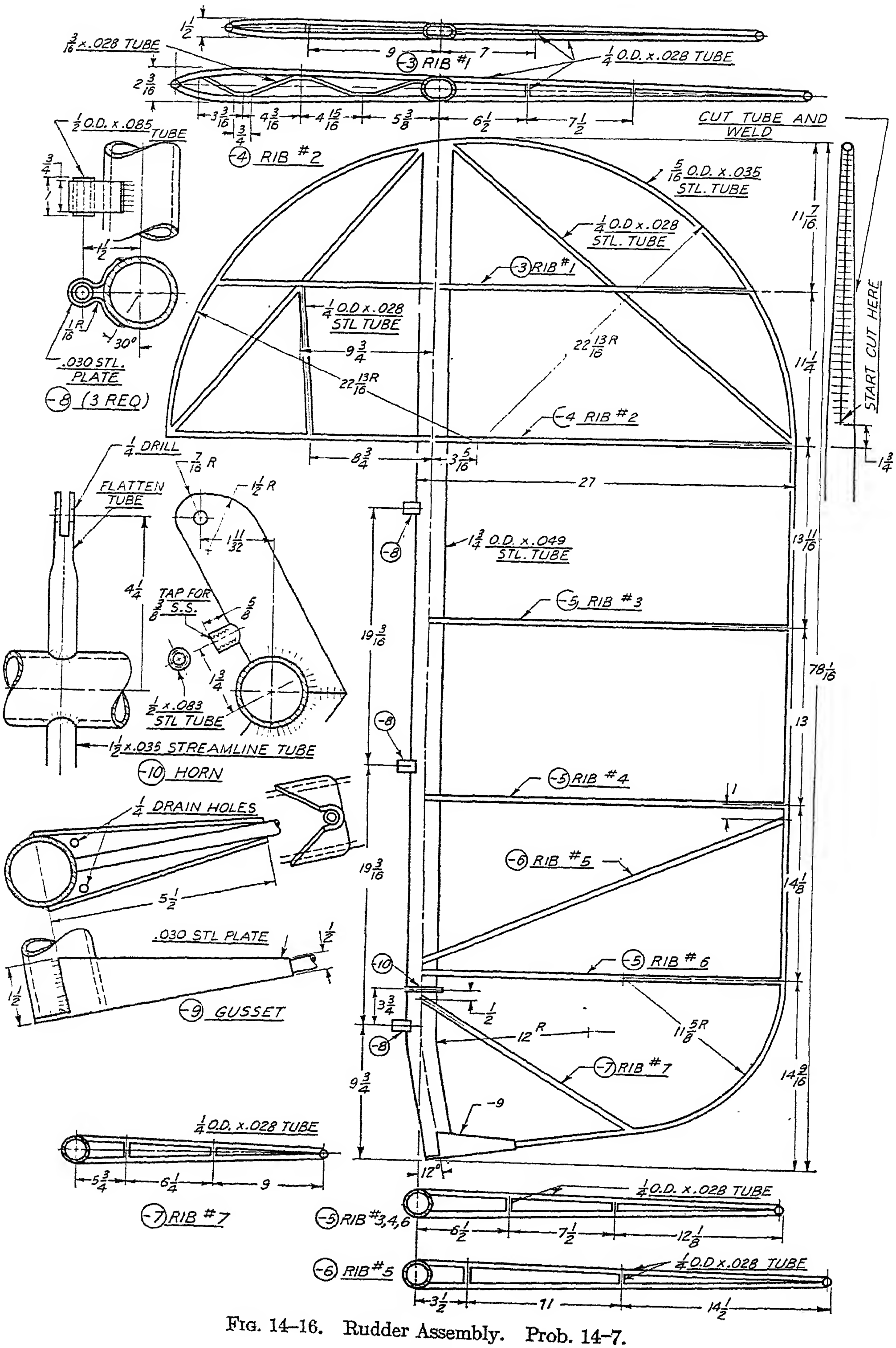


Fig. 14–16. Rudder Assembly. Prob. 14-7.

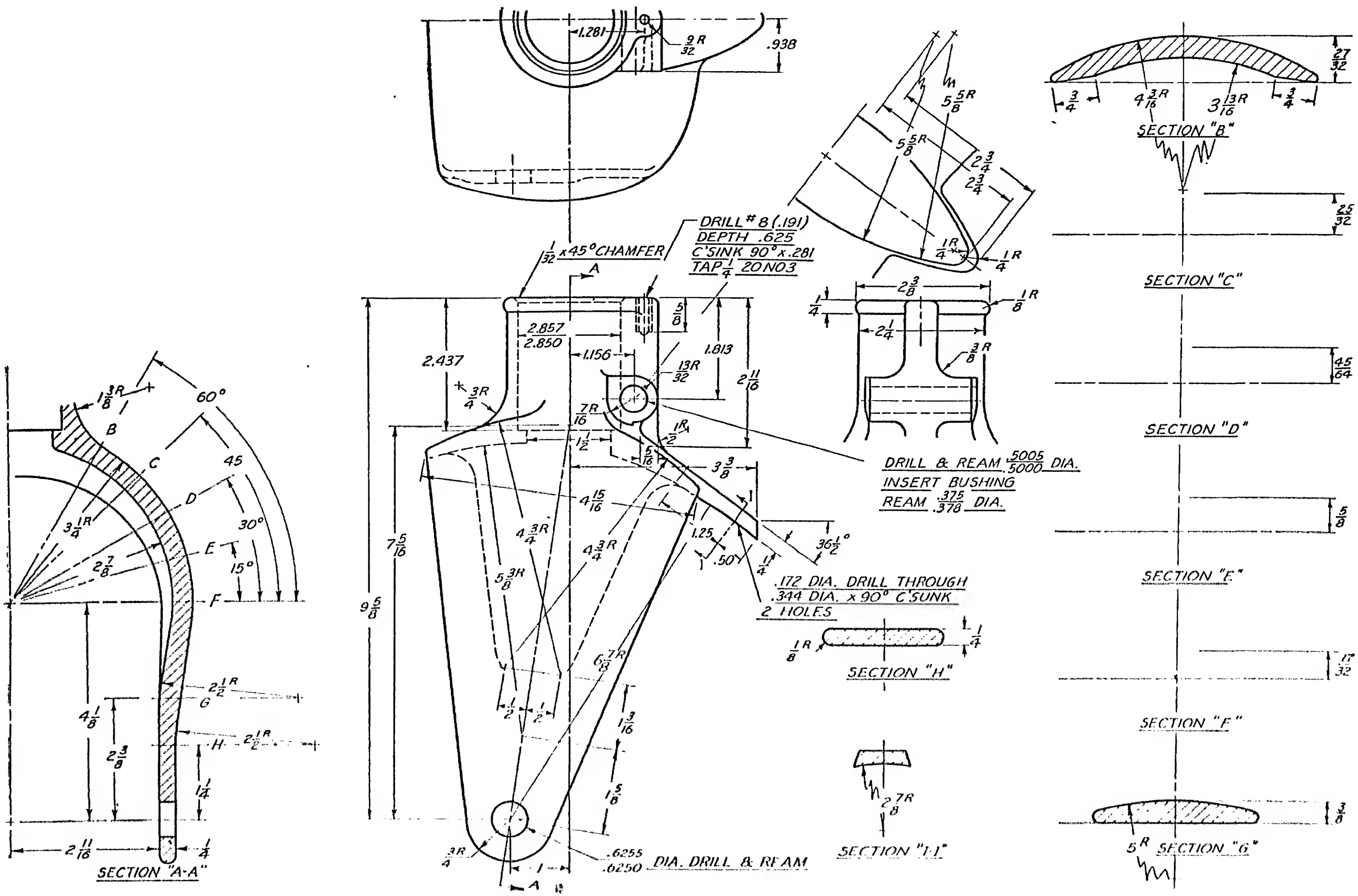


Fig. 14-17. Nose Fork. Prob. 14-8.

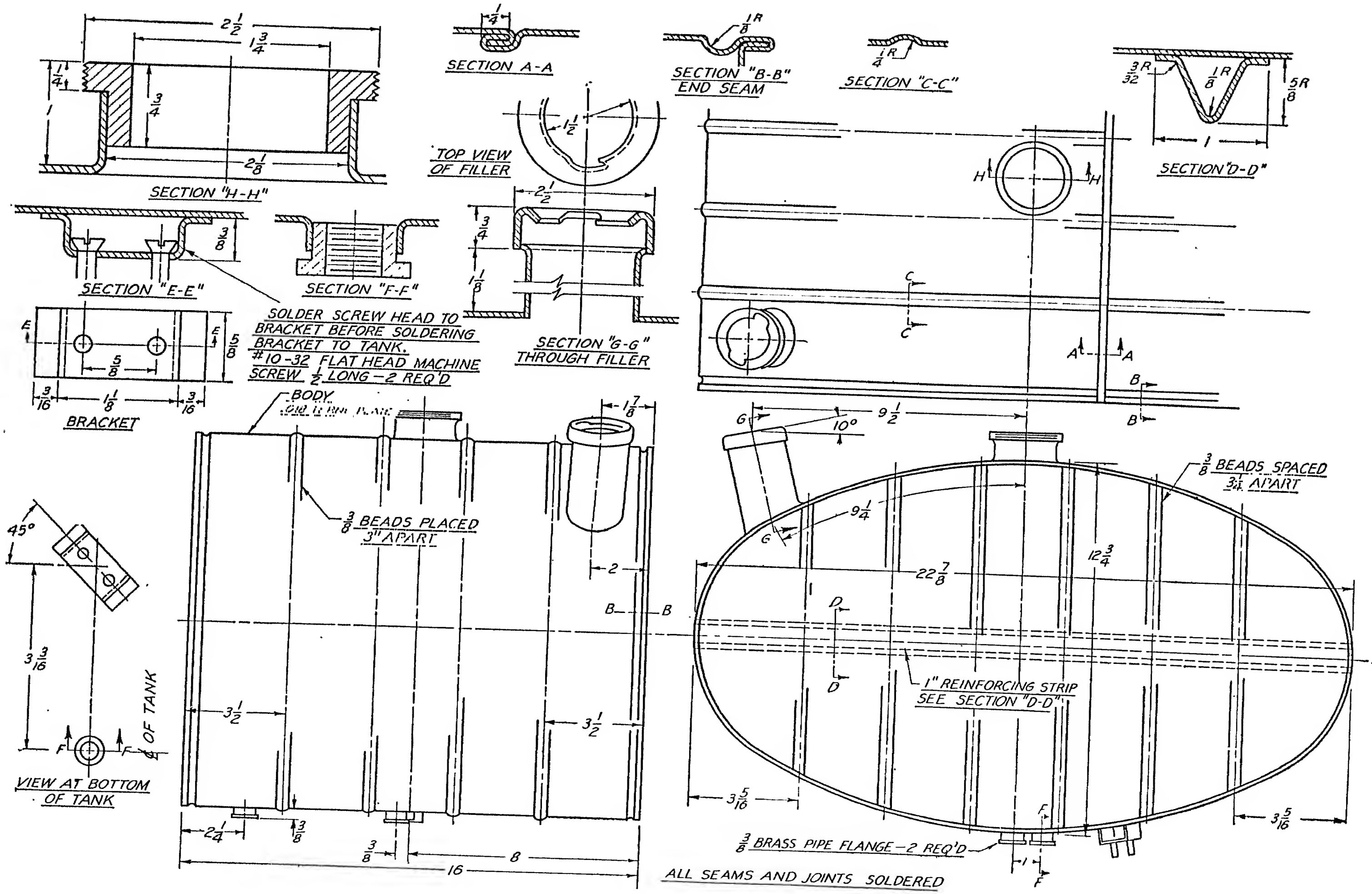


Fig. 14–18. Fuel Tank. Prob. 14–9.

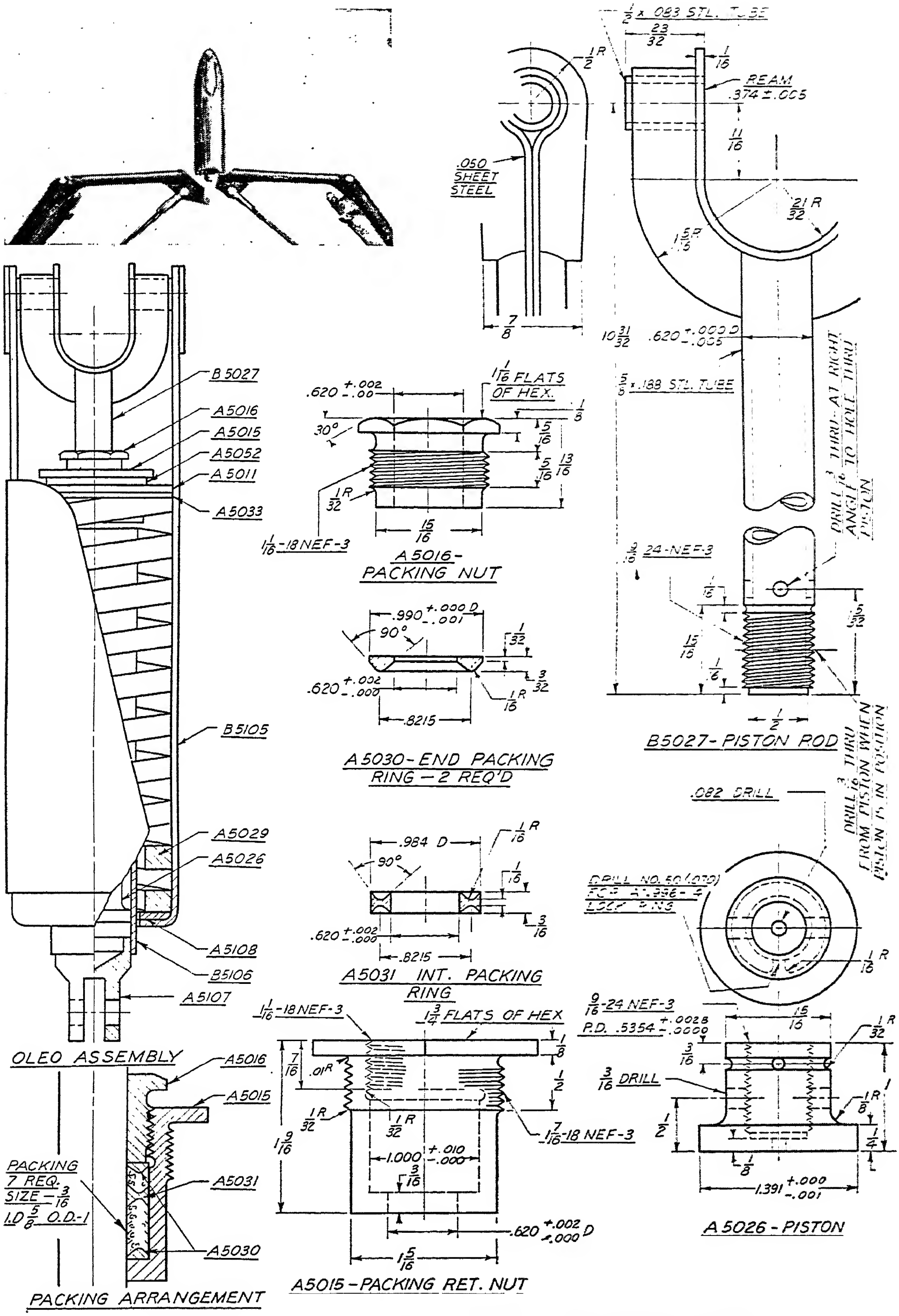


Fig. 14–19. Landing Gear Shock Absorber. Probs. 14–10 to 14–26.

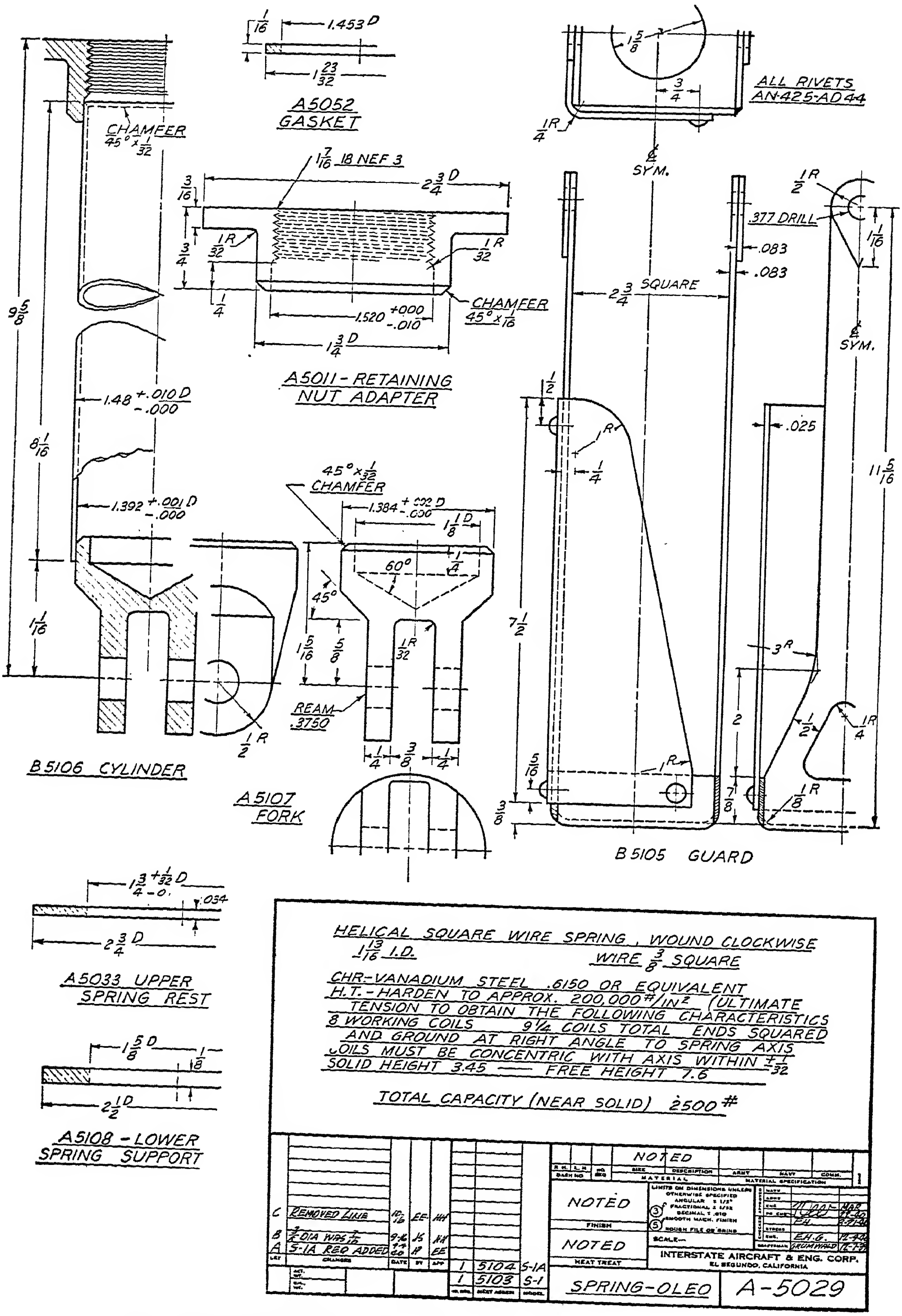


FIG. 14-20. Landing Gear Shock Absorber. Probs. 14-10 to 14-26.

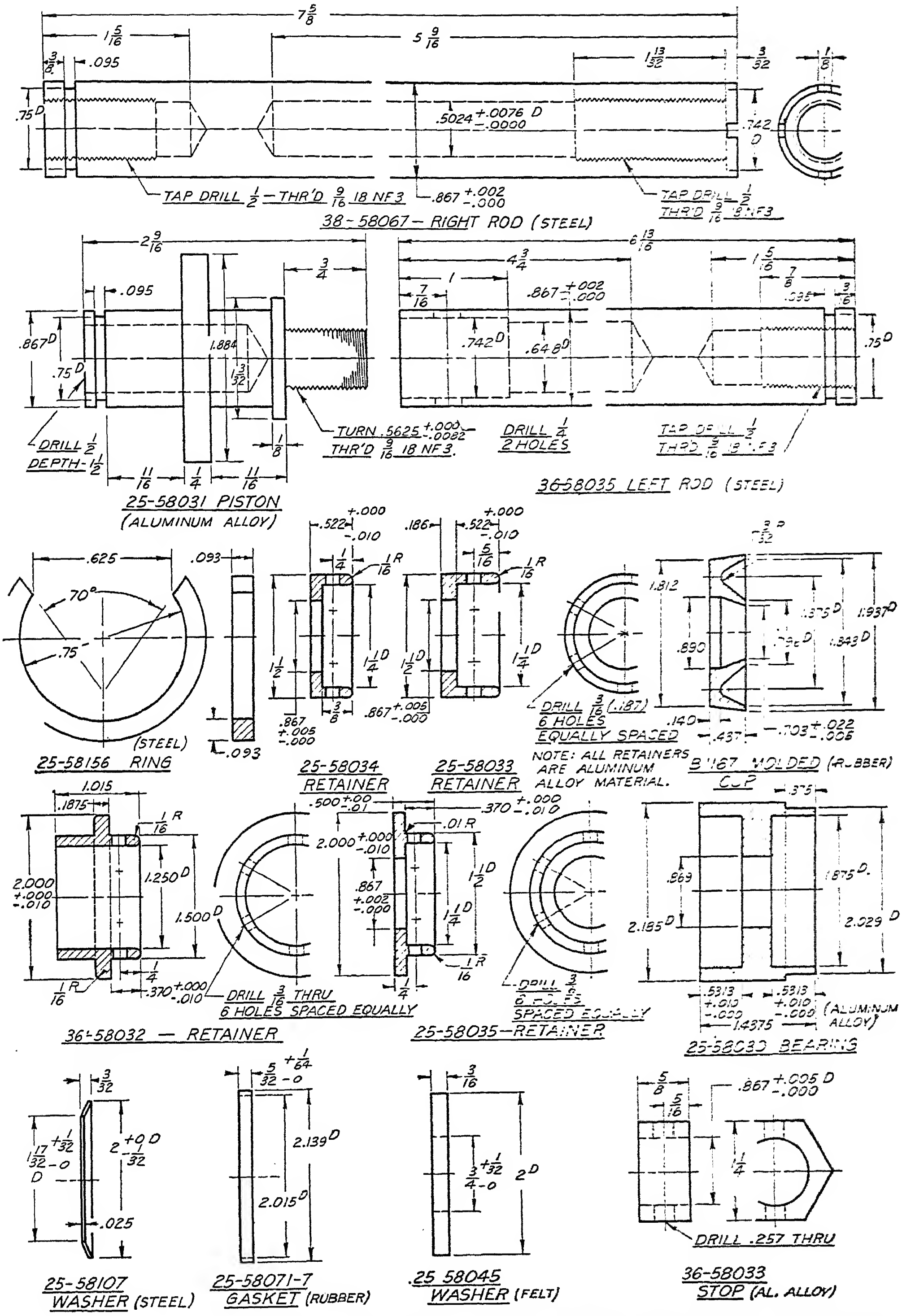


Fig. 14-21. Hydraulic Flap Operating Cylinder Details. Probs. 14-37 to 14-38. Prob. 14-42.

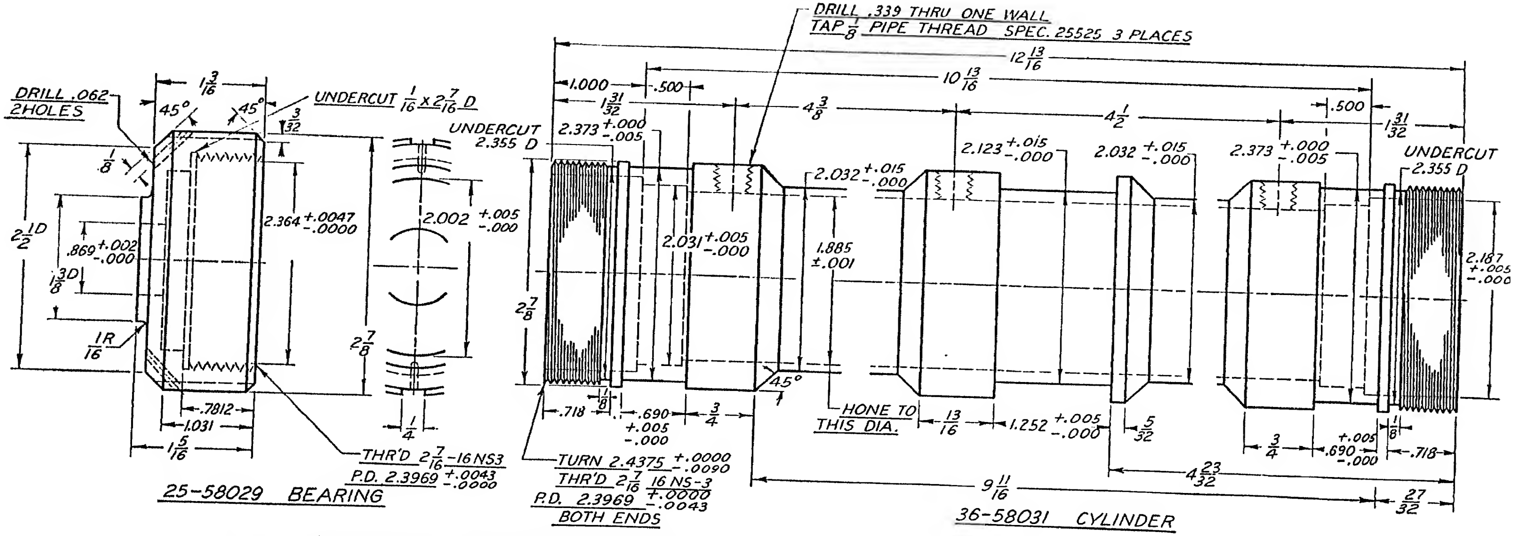


FIG. 14–22. Hydraulic Flap Operating Cylinder Details. Probs. 14–40, 14–41, 14–42.

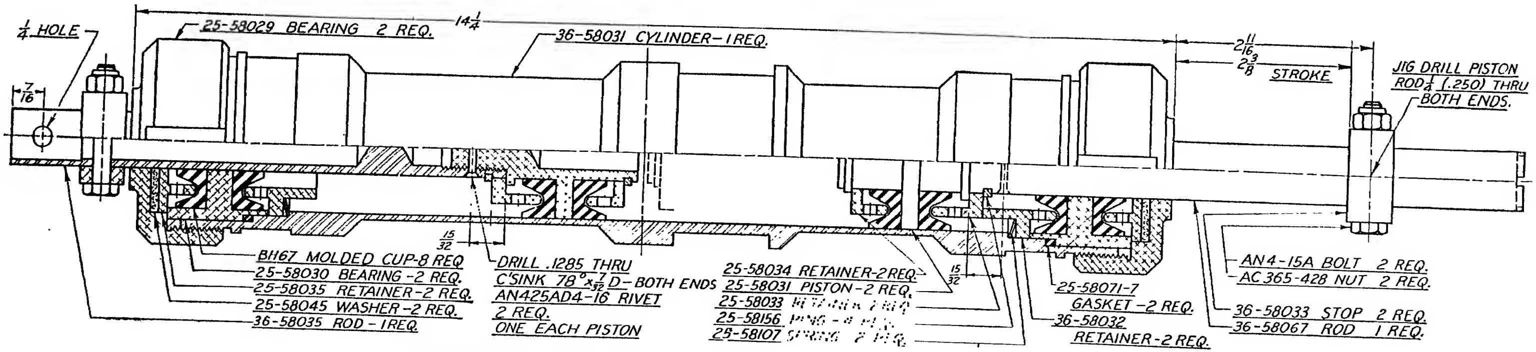


FIG. 14–23. Hydraulic Flap Operating Cylinder Assembly. Prob. 14–42.

Probs. 14–43 to 14–50. Figs. 14–24 to 14–26 show details and assembly for a section through gears of an EXTERNAL ENERGIZER FOR INERTIA STARTERS made by Eclipse Aviation, Division of Bendix Aviation Corporation, Bendix, N.J.

Probs. 14–43 to 14–49. Figs. 14–25 and 14–26. — Make detail drawings. Show complete views and consider choice and treatment of views and scale. Prob. 14–43, BEARING CAP. Prob. 14–44, HOUSING GEAR. Prob. 14–45, BARREL SHAFT. Prob. 14–46, CROWN GEAR. Prob. 14–47, DRIVING PINION. Prob. 14–48, FRONT DRIVE SHAFT. Prob. 14–49, BOLT LOCK (draw to enlarged scale).

Prob. 14–50. Figs. 14–24 to 14–26. — Make an ASSEMBLY GEAR SECTION OF THE EXTERNAL ENERGIZER FOR INERTIA STARTERS as shown in Fig. 14–26 including notes, etc.

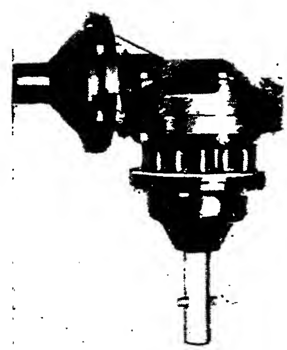


FIG. 14–24.

Gear Section of the External Energizer for Inertia Starters.

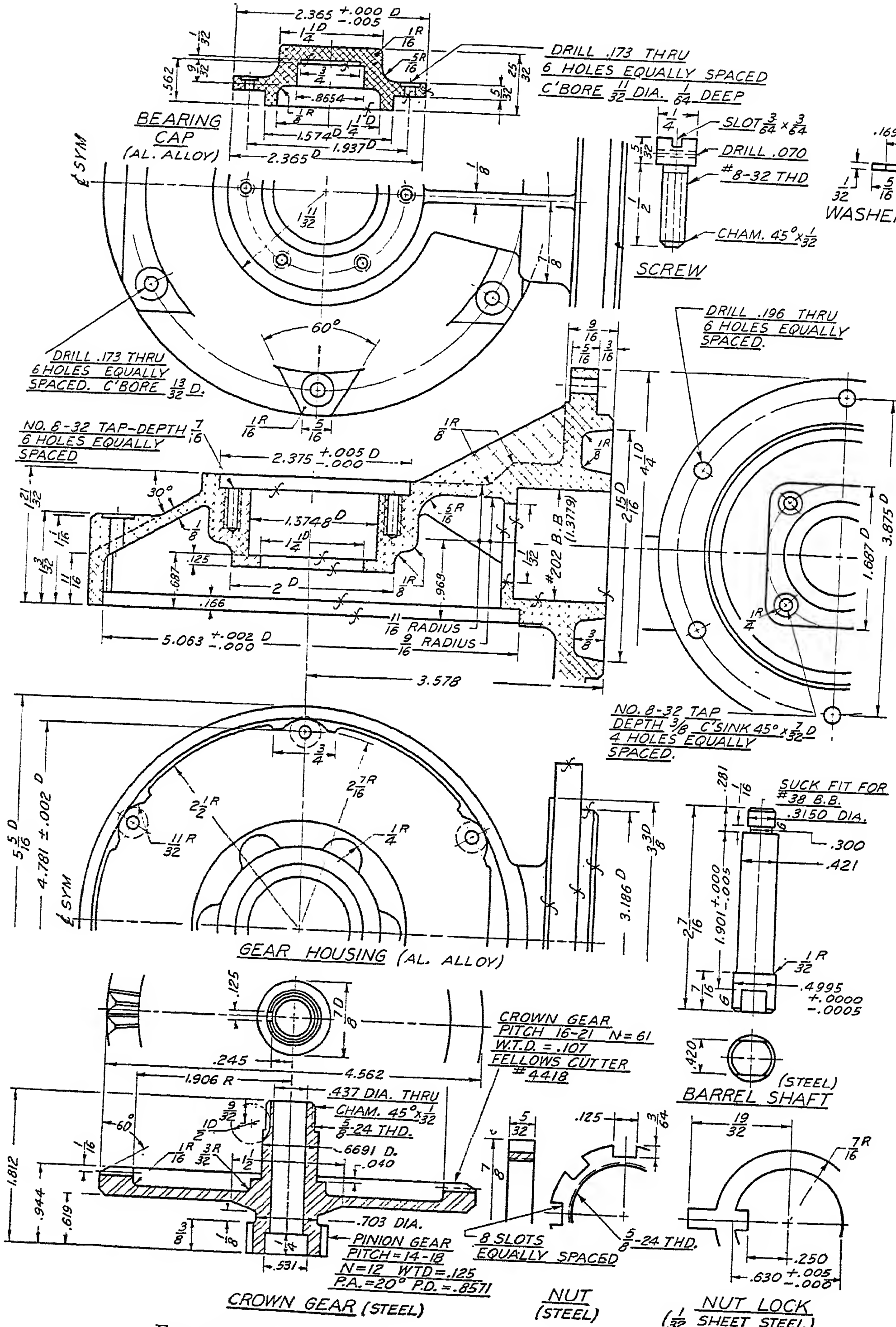
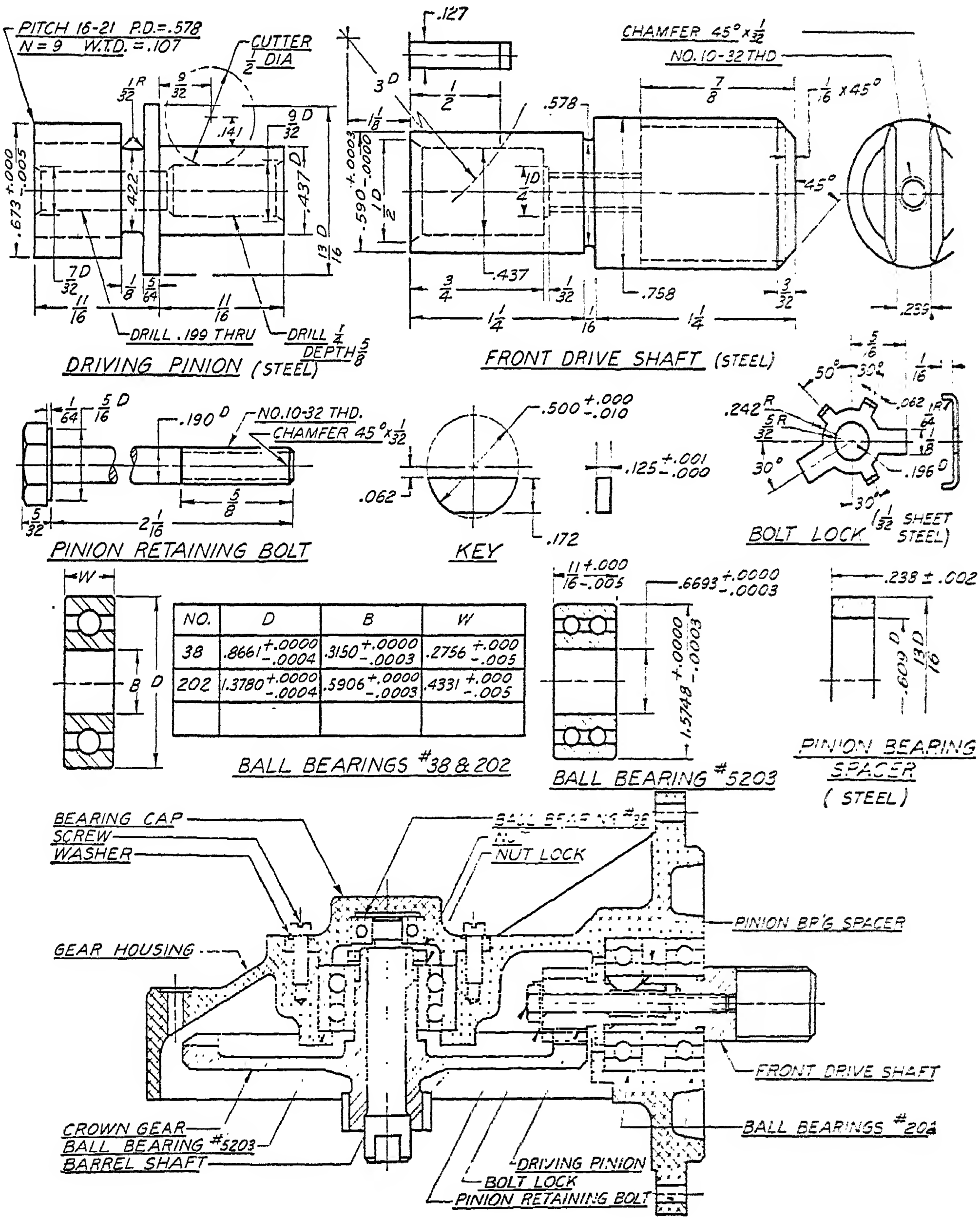


FIG. 14-25. Details of the Gear Section. Probs. 14-43 to 14-50.



NO.	D	B	W
38	.8661 +.0000 −.0004	.3150 +.0000 −.0003	.2756 +.000 −.005
202	1.3780 +.0000 −.0004	.5906 +.0000 −.0003	.4331 +.000 −.005

FIG. 14-26.

CHAPTER XV

AIRCRAFT ENGINES

15–1. Aircraft engines have made flight possible, constant development of the light, small power plant has been the basis of all the progress in aviation since the Wright brothers made their first power flight. Airplane engines must be light in weight, compact, economical of fuel and absolutely reliable under variable conditions. The study of airplane engines should be made in books devoted to the various phases of design, operation and maintenance, the specifications and instruction books of the manufacturers, and by shop, testing laboratory and flight experience with aircraft engines.

15–2. Aircraft Engine Drawings. — This chapter is intended to indicate the general character of aircraft engine drawings and not to illustrate or describe the different types of air or liquid cooled engines or the arrangements of cylinders — in-line, V, W, radial, etc. For this purpose a few engines are illustrated from which parts have been selected to serve as drawing problems.

15–3. PROBLEMS. — The illustrations and drawings will suggest other problems as well as the ones specified. In some cases the student is expected to work out details and develop the required information on his drawing. The sizes of sheets and other preliminary information is not given but is to be decided upon in consultation with the instructor.

Probs. 15–1 to 15–10. The Lycoming, Model 0–145, engine illustrated in Figs. 15–1 to 15–12, is made by the Lycoming Division of the Aviation Manufacturing Corporation, Williamsport, Pa. It is a 50–75 hp. four cylinder direct drive, horizontally opposed air cooled engine. A sectional view is shown in Fig. 8–1.

Prob. 15–1. Fig. 15–2. — Make a drawing of the INTAKE VALVE as indicated for a Lycoming Aviation Engine.

Prob. 15–2. Fig. 15–3. — Make a drawing of the EXHAUST VALVE for a Lycoming Aviation Engine. Drawing to be similar to Fig. 15–2. Show an enlarged view of a part of the valve head (four times full size). Valve head to be polished, round off edge with max. radius of .015. Stem must be ground straight to a point within ⅝ of the rounded (top) surface of the valve head. Note at (A): 48° scleroscope min. hardness stem. Note at (B): 60° scleroscope min. hardness. Valve stem to run true with head within .002. Note at (C): $\frac{.300}{.295}$ DIA. Note at (E): $\frac{.277}{.271}$ DIA.

Prob. 15–3. Fig. 15–4. — Make a forging drawing of the RIGHT-HAND VALVE ROCKER for a Lycoming Aviation Engine.

Prob. 15–4. Fig. 15–4. — Make a working drawing of the RIGHT-HAND VALVE ROCKER as indicated, for a Lycoming Aviation Engine. Add the following notes: 1. Make from 45445 forging. 2. Machine where shown. 3. Carburize surface "*A*" to depth of .015 – .030. 4. Heat Treat S.A.E. 3115 II. 5. Scleroscope hardness surface "*A*" 80°–90°.

Prob. 15–5. Figs. 15–5 and 15–6. — Make a working drawing of the CONNECTING ROD for a Lycoming Aviation Engine. Note the graphic scale which is to be used as described in connection with Fig. 11–24.

Prob. 15–6. Figs. 15–5 and 15–6. — Make detail working drawings of the PISTON PIN, PISTON-PIN PLUG, CONNECTING ROD BOLT AND NUT. Note the graphic scale to be used as explained for Fig. 11–24. Add the following notes to drawing of piston pin: At (A) " Grind and lap. Surface must be smooth and true within .0002." At (B) " Grind and lap. Surface must be square with outside diameter within .002 indicator reading and flat within .002 indicator reading." At (C) " These dia's must be concentric within .015 total indicator reading." Material: S.A.E. X-1020 C.D. Steel. Other notes to be added include: 1. Scleroscope hardness to be taken when pin is held rigidly in clamp shaped to fit pin. 2. Scleroscope hardness to be 80°–90° uniform for each pin with a minimum of 75° at a point ¼ from each end. 3. To be drilled and countersunk after carburizing, hole must be soft. 4. Pack harden 3/64 deep. 5. All scale must be removed from hole.

Prob. 15–7. Figs. 15–5 and 15–6. — Make a working drawing of the CONNECTING ROD for a Lycoming Aviation Engine. Note the graphic scale to be as explained for Fig. 11–24.

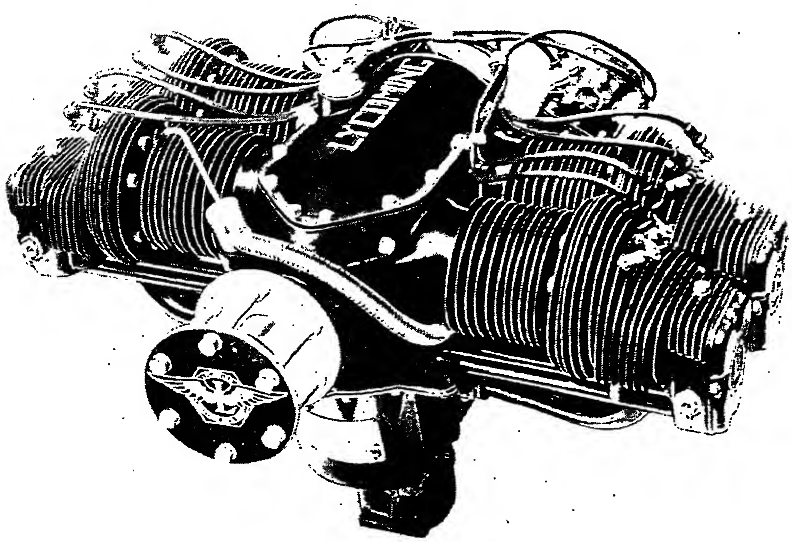


FIG. 15–1. Lycoming, 0–145, 50–75 H.P. Direct Drive Engine. (*Lycoming Division, Aviation Manufacturing Corporation.*)

Prob. 15–8. Figs. 15–5 and 15–6. — Make a forging drawing for the CONNECTING ROD.

Prob. 15–9. Figs. 15–5, 15–7, and 15–8. — Make a working drawing of the PISTON similar to Fig. 15–8, for a Lycoming Aviation Engine. Check every part until you thoroughly understand the shape of the piston.

Prob. 15–10. Figs. 15–9 to 15–12 inclusive. — Make a CRANKSHAFT ASSEMBLY drawing for a Lycoming Aviation Engine, as suggested in Fig. 15–11. Parts not shown on Fig. 15–12 are to be supplied as the drawing is worked up. Fig. 15–10 shows the crank case with the bearings for the crankshaft.

Prob. 15–11. Figs. 15–9 to 15–12 inclusive. — Make a working drawing of the CRANKSHAFT for a Lycoming Aviation Engine, using the information given on Fig. 15–12.

Prob. 15–12. Figs. 15–5 to 15–9. — Make a sectional assembly drawing of the PISTON and CONNECTING ROD on a plane perpendicular to the axis of the crankshaft.

Prob. 15–13. Same as Prob. 15–12 on a plane perpendicular to the piston pin.

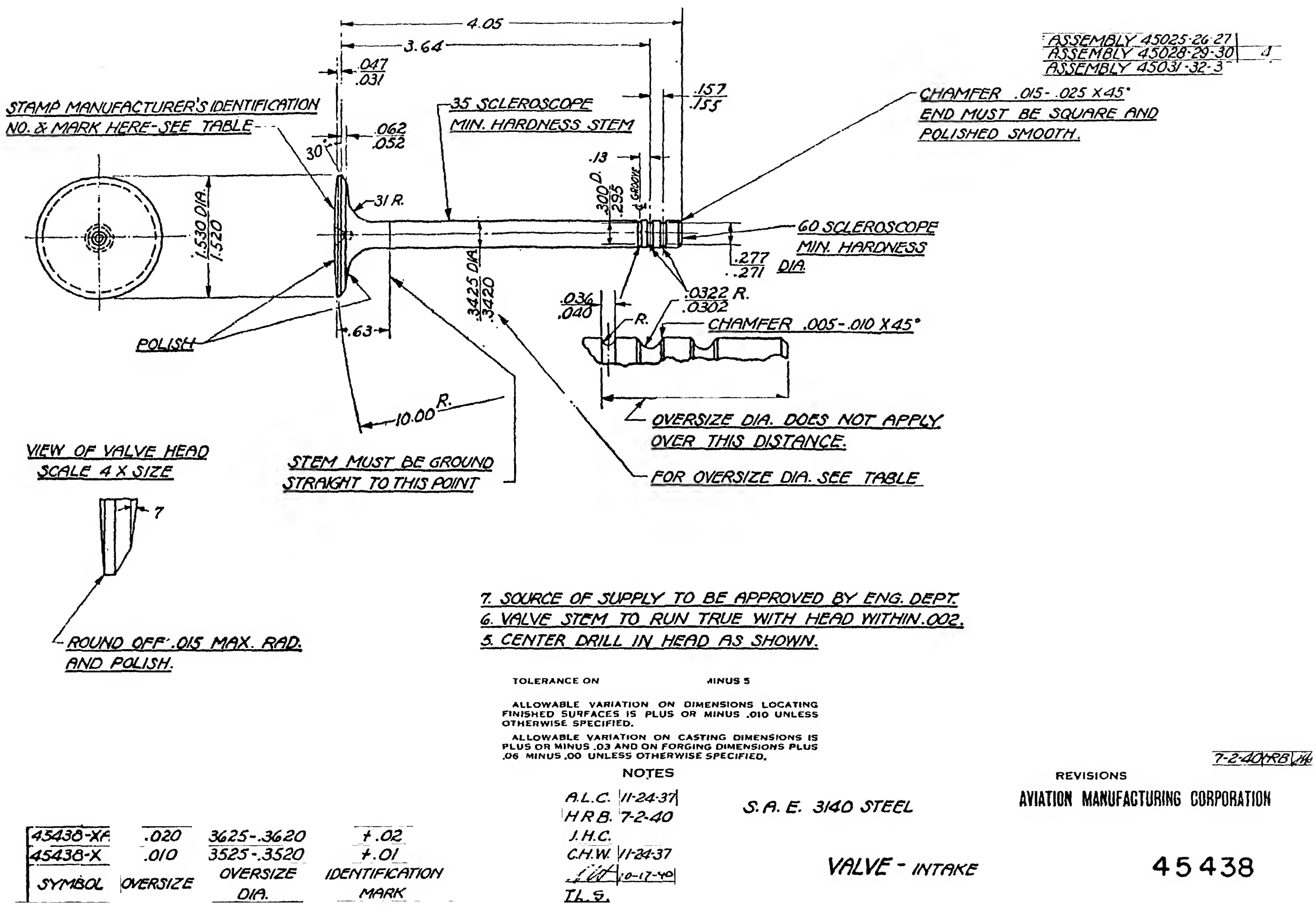


Fig. 15–2 Intake Valve Prob. 15–1

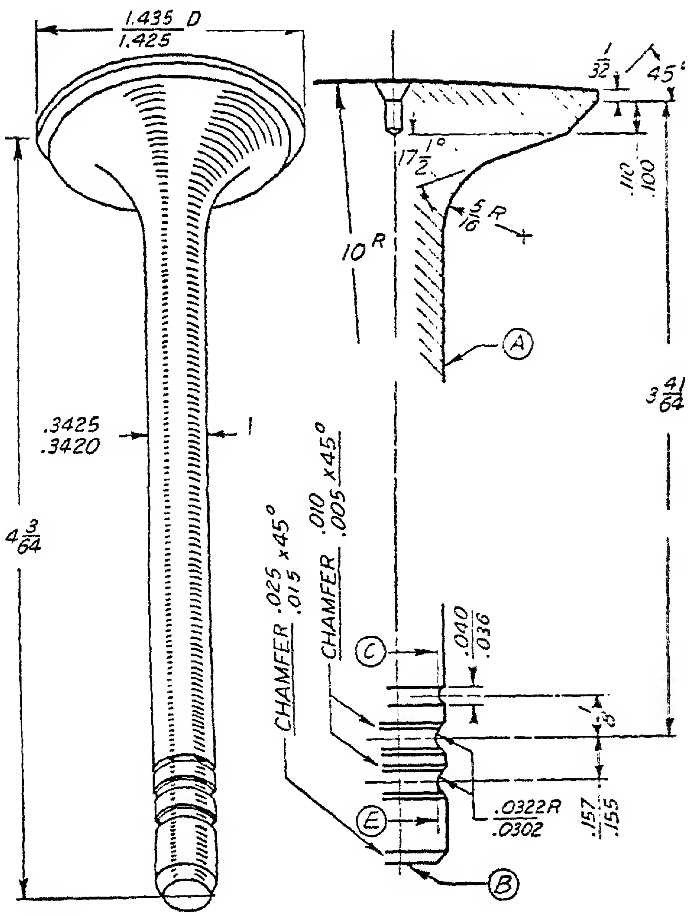


FIG. 15-3. Exhaust Valve. Prob. 15-2.

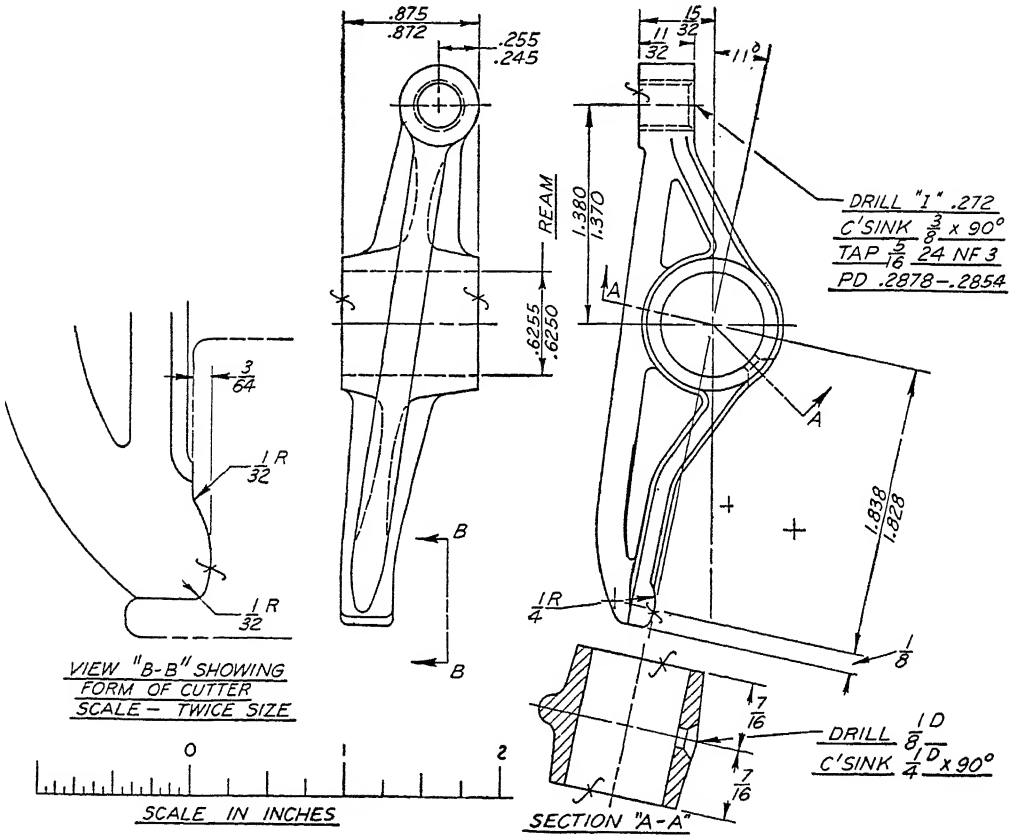


FIG. 15-4. Right-Hand Valve Rocker. Probs. 15-3 and 15-4.

Probs. 15–14 to 15–18. The Kinner, Model B-54, engine illustrated in Figs. 15–13 to 15–15, is made by the Kinner Motors, Inc., of Glendale, California. It is a 125 hp. five cylinder, air cooled radial engine.

Prob. 15–14. Fig. 15–14. — Make a detail working drawing of the HUB RETAINING NUT for the propeller hub (No. 20 S.A.E. Spline Shaft) for a Kinner Aviation Engine.

Prob. 15–15. Fig. 15–14. — Same as Prob. 15–14 for the HUB FRONT CONE.

Prob. 15–16. Fig. 15–14. — Same as Prob. 15–14 for the HUB REAR CONE.

Prob. 15–17. Fig. 15–14. — Make an assembly drawing of the PROPELLER HUB (No. 20 S.A.E.) as shown on the lower half of the drawing. The parts for which dimensions are not given are to be taken off with the dividers — the sectional assembly is shown half size in Fig. 15–14. It should be drawn full size.

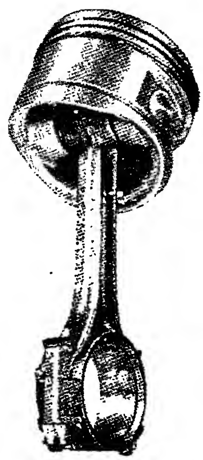


Fig. 15–5. Aluminum Alloy Piston and Connecting Rod Assembly.

Prob. 15–18. Figs. 15–13 and 15–15. — Draw an outline assembly drawing for the Kinner Aviation Engine as shown. This is part of an installation drawing. The views are to be drawn to a scale of 3 inches = 1 foot. The graphic scale shown was this size on the drawing before reduction for use in the book. Use dividers and this scale to obtain distances.

Probs. 15–19 to 15–21. The Ranger 6–440C–5 engine illustrated in Figs. 15–16 to 15–19 is made by Ranger Aircraft Engines, Division of Fairchild Engine & Airplane Corporation, Farmingdale, L. I., New York. It is a 200 hp. six cylinder air cooled, inverted, in-line, direct drive engine.

Prob. 15–19. Fig. 15–17. — Make a detail working drawing of the EXHAUST VALVE for the Ranger Aviation Engine.

Prob. 15–20. Fig. 15–18. — Make a detail working drawing of the CRANKSHAFT GEAR for the Ranger Aviation Engine. Show one or two views in section and necessary other views.

Prob. 15–21. Fig. 15–19. — Make a complete detail working drawing for the PISTON for the Ranger Aviation Engine. Show all necessary views, including sections, enlarged part section of grooves, ribs, finished surfaces, etc.

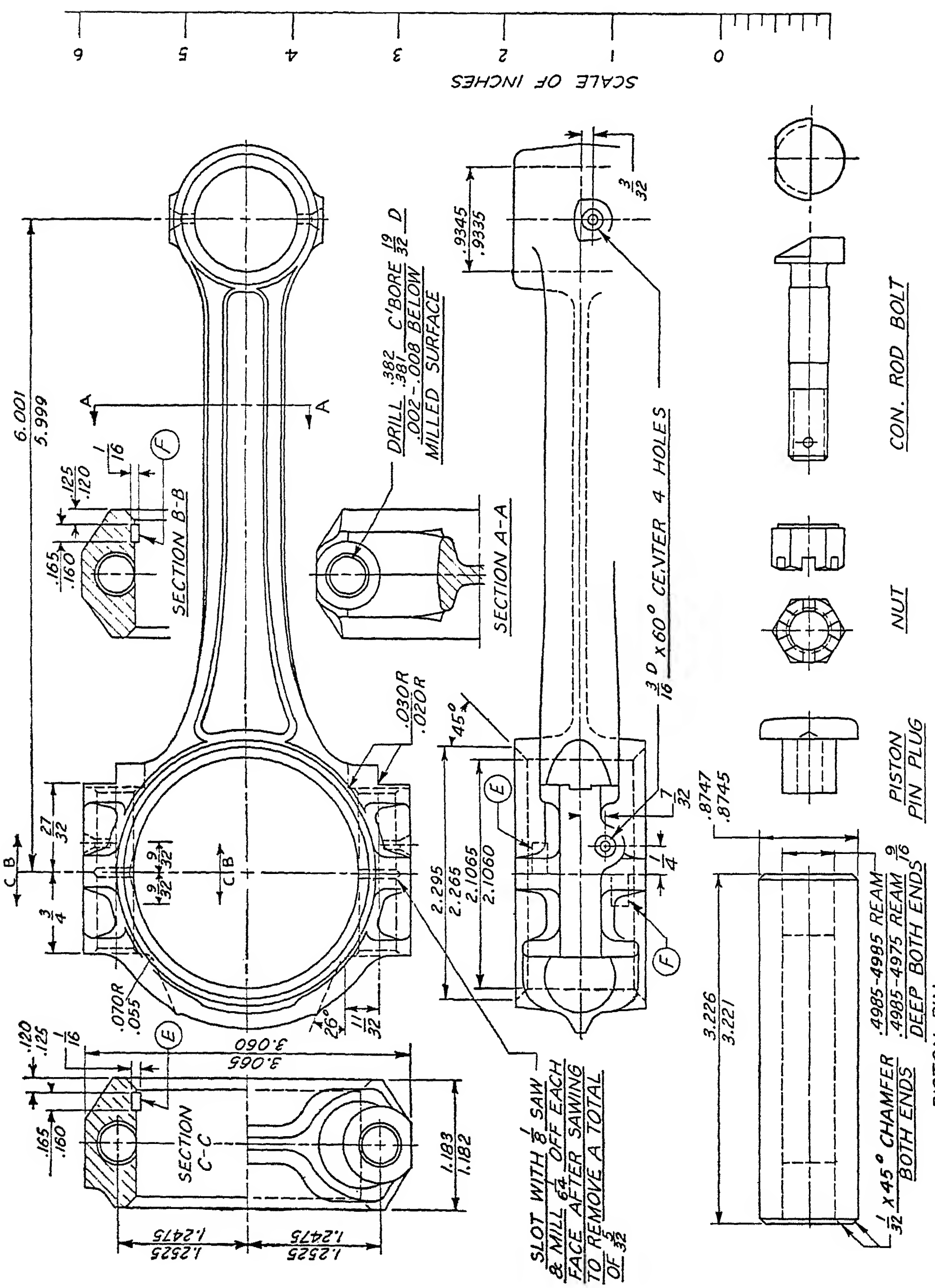


FIG. 15-6. Connecting Rod. Probs. 15-5, 15-6, 15-7, 15-11, 15-12.

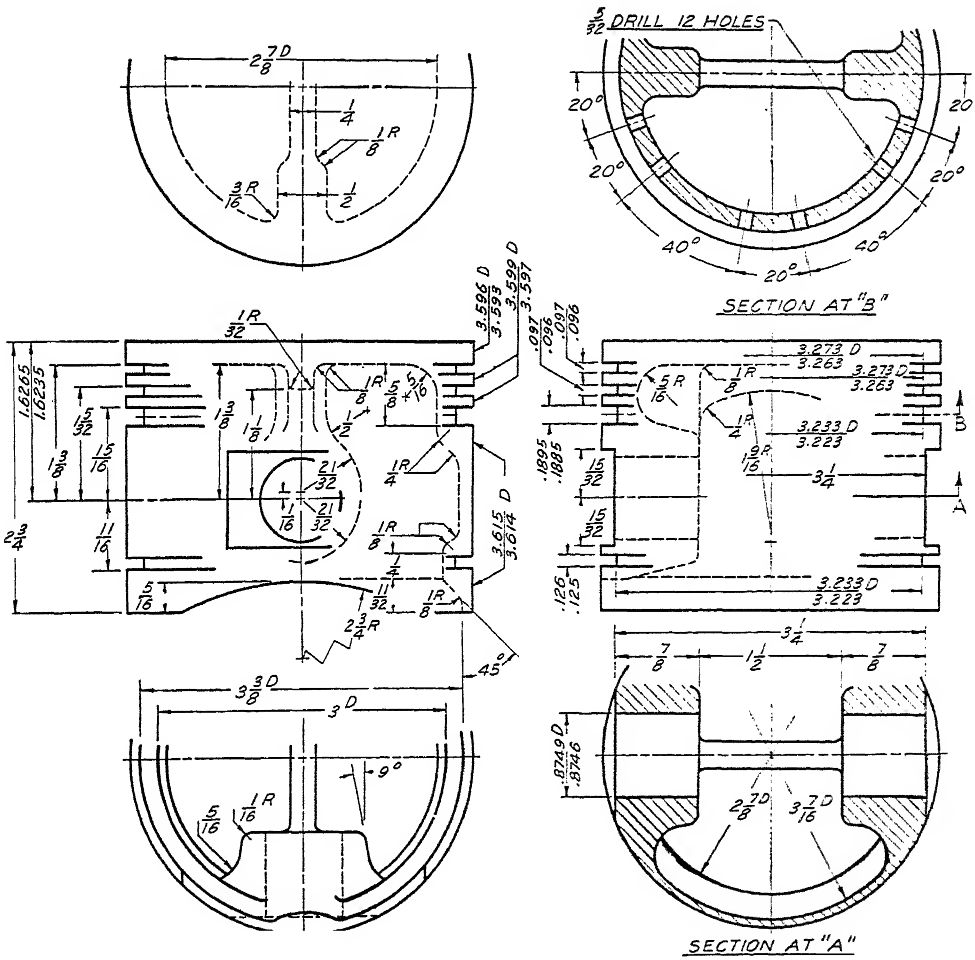


FIG. 15-7. Piston. Probs. 15-8, 15-11, 15-12.

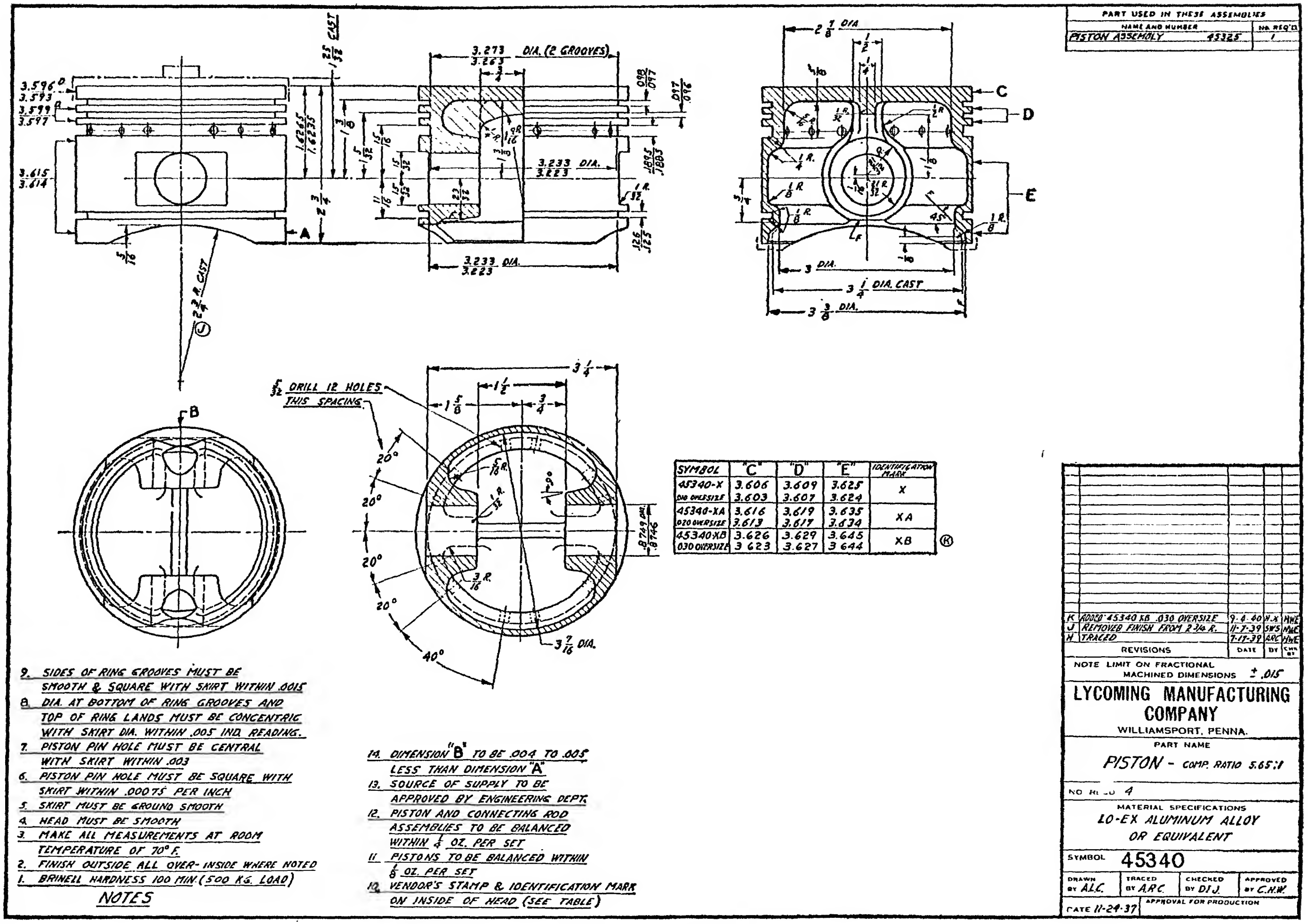


FIG. 15-8. Piston.

Fig. 15–9. Crankshaft.

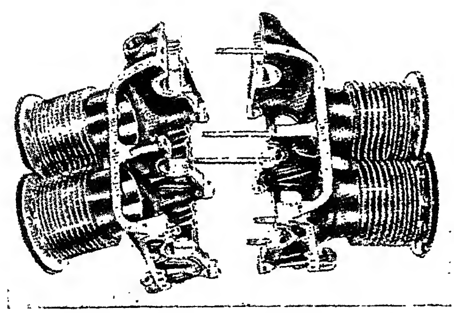


Fig. 15–10. Crankcase and Integral Cylinders.

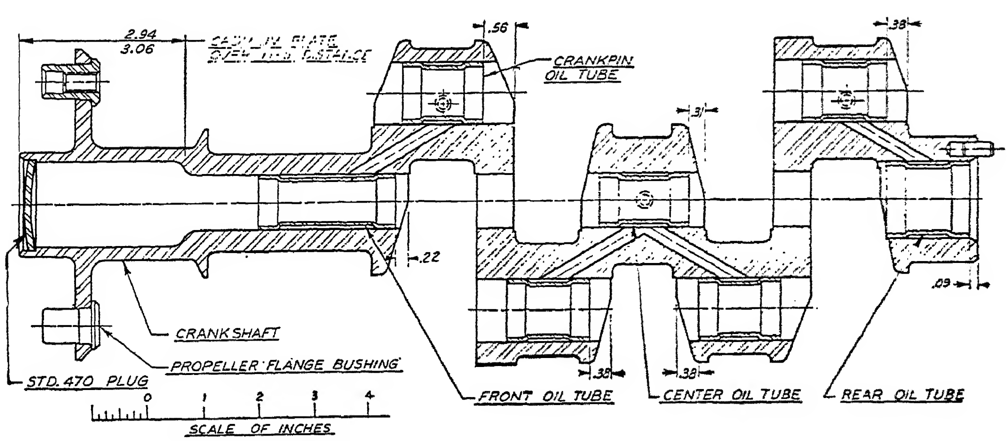


Fig. 15–11. Crankshaft Assembly. Probs. 15–9 and 15–10.

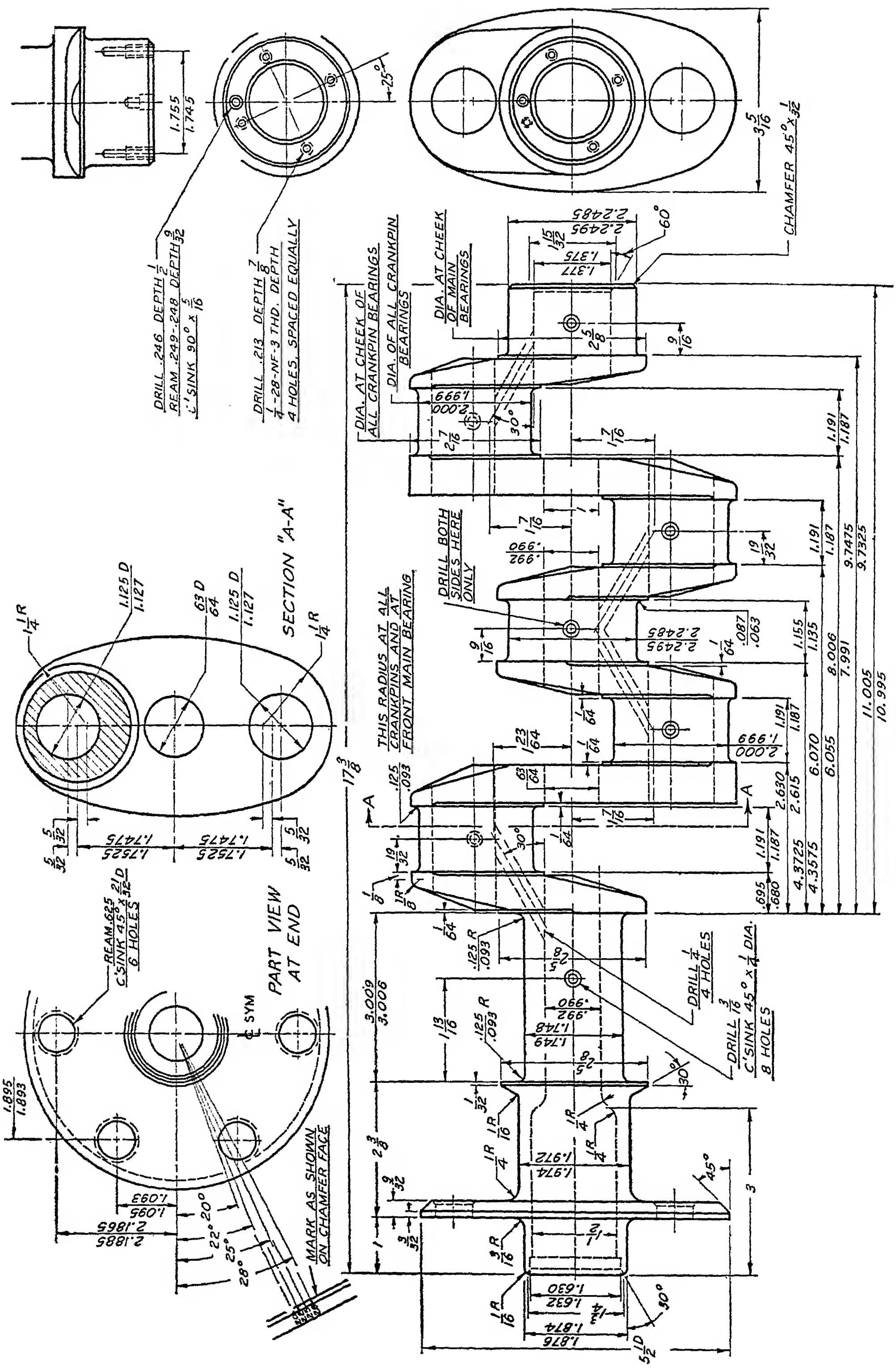


FIG. 15-12. Crankshaft Detail. Probs. 15-9 and 15-10.

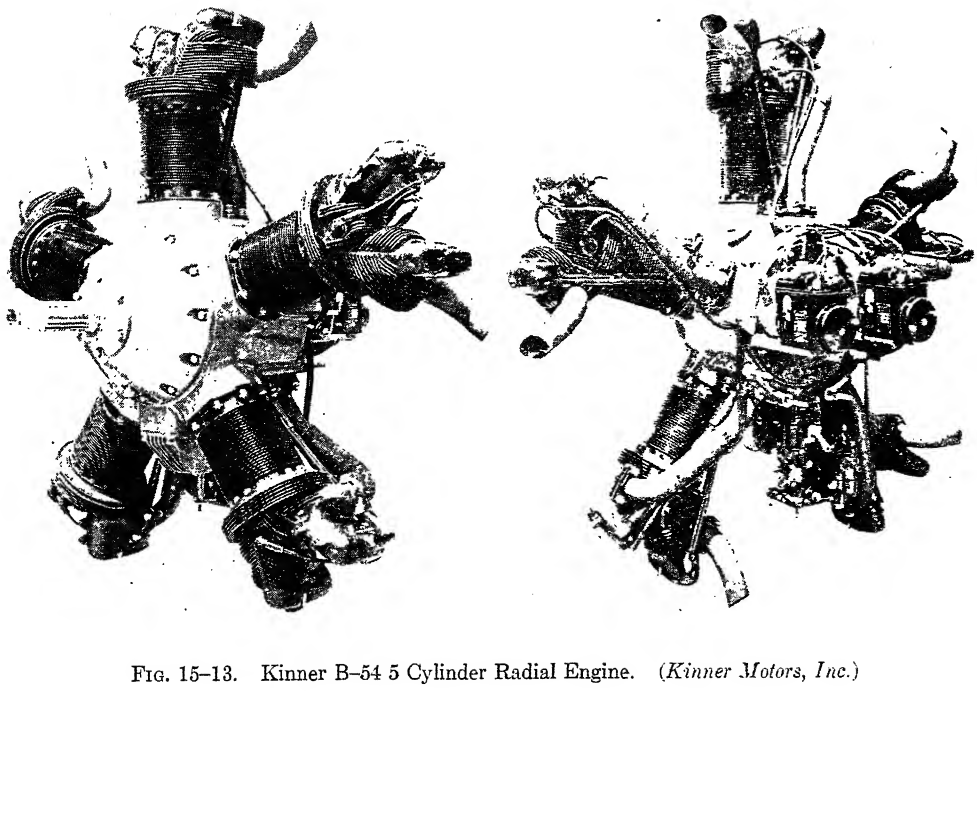


FIG. 15–13. Kinner B–54 5 Cylinder Radial Engine. *(Kinner Motors, Inc.)*

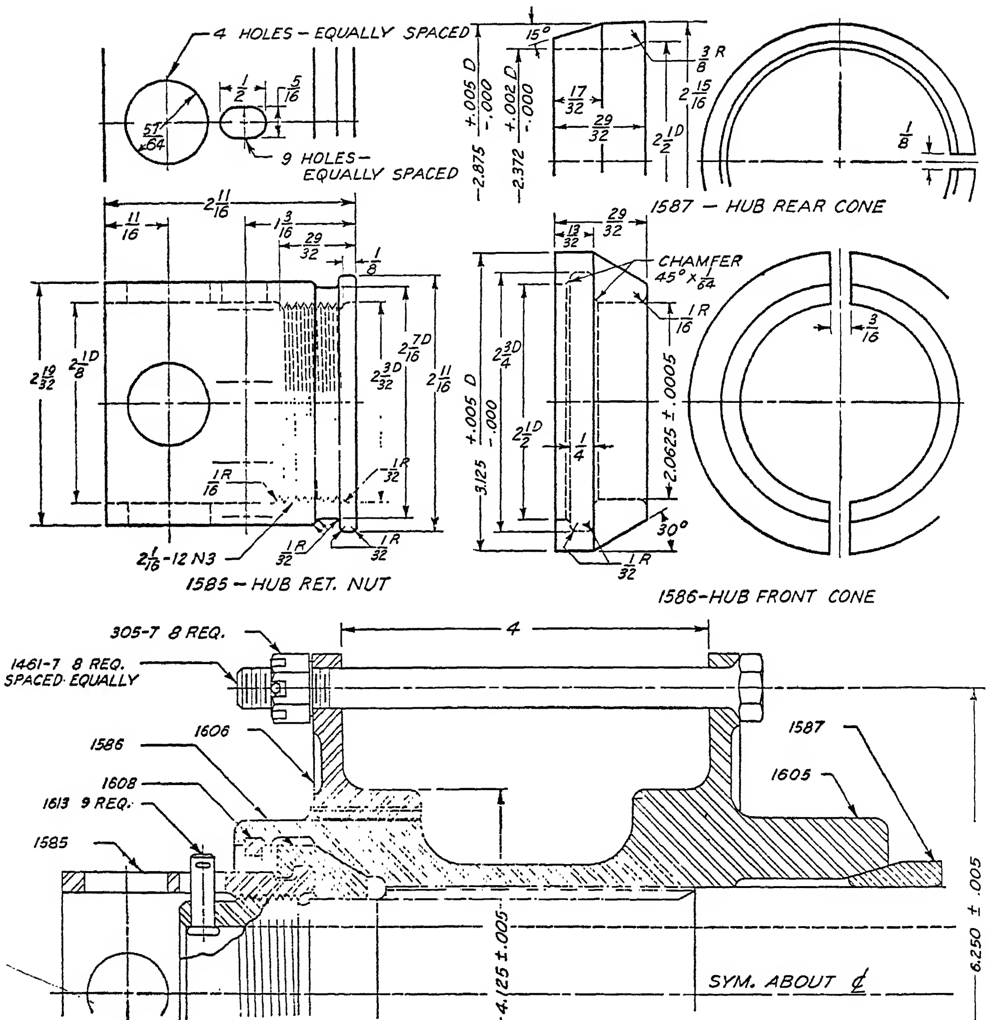
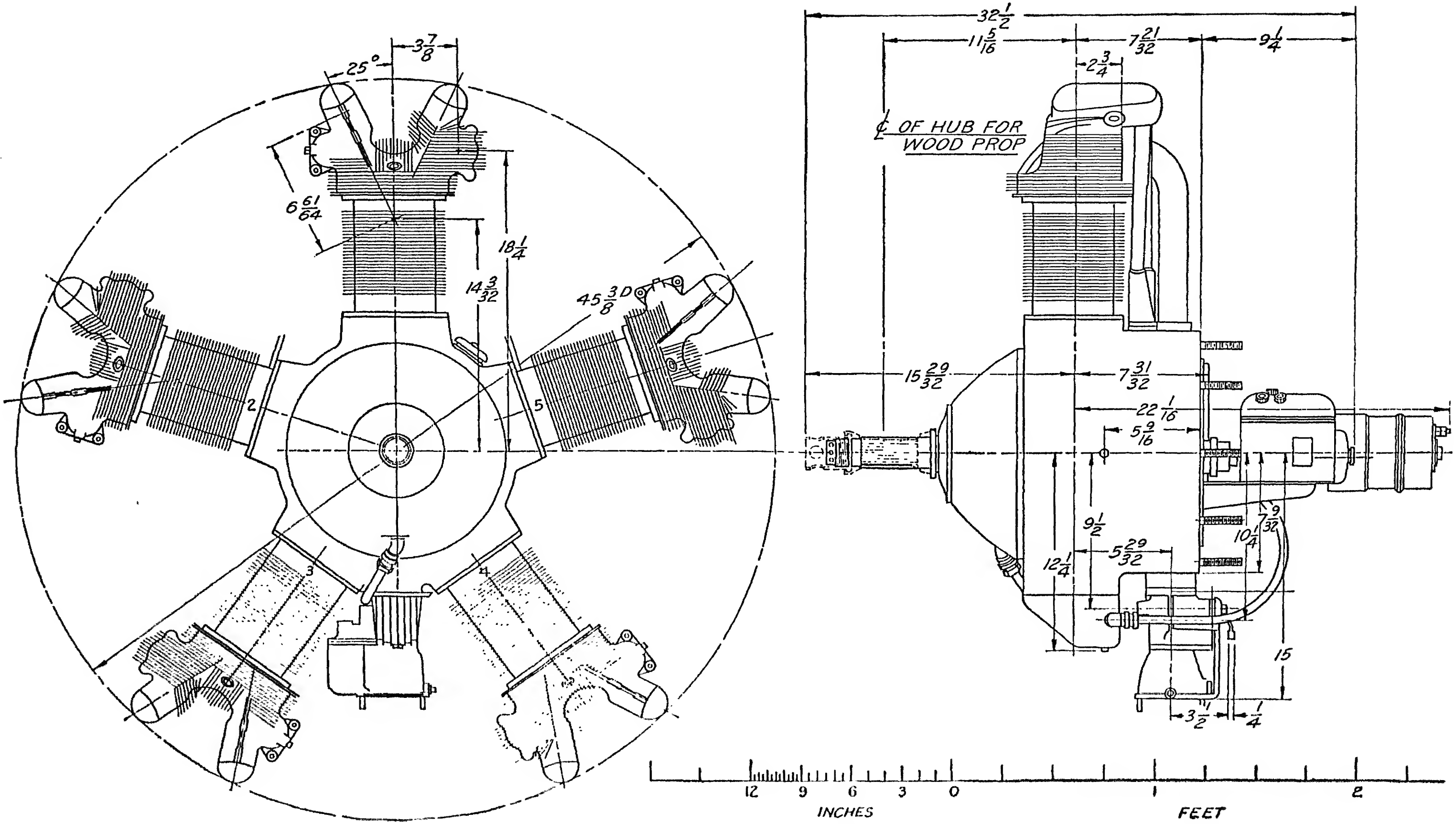


FIG. 15-14. Propeller Hub Details. Probs. 15-14, 15-15. 15-16, 15-17.



Outline Assembly. Prob. 15-18.

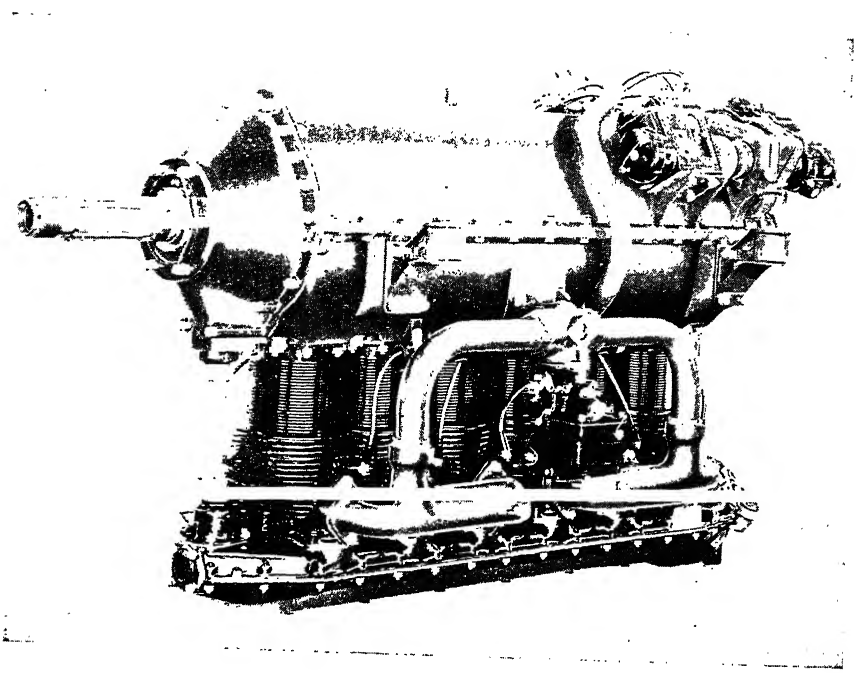
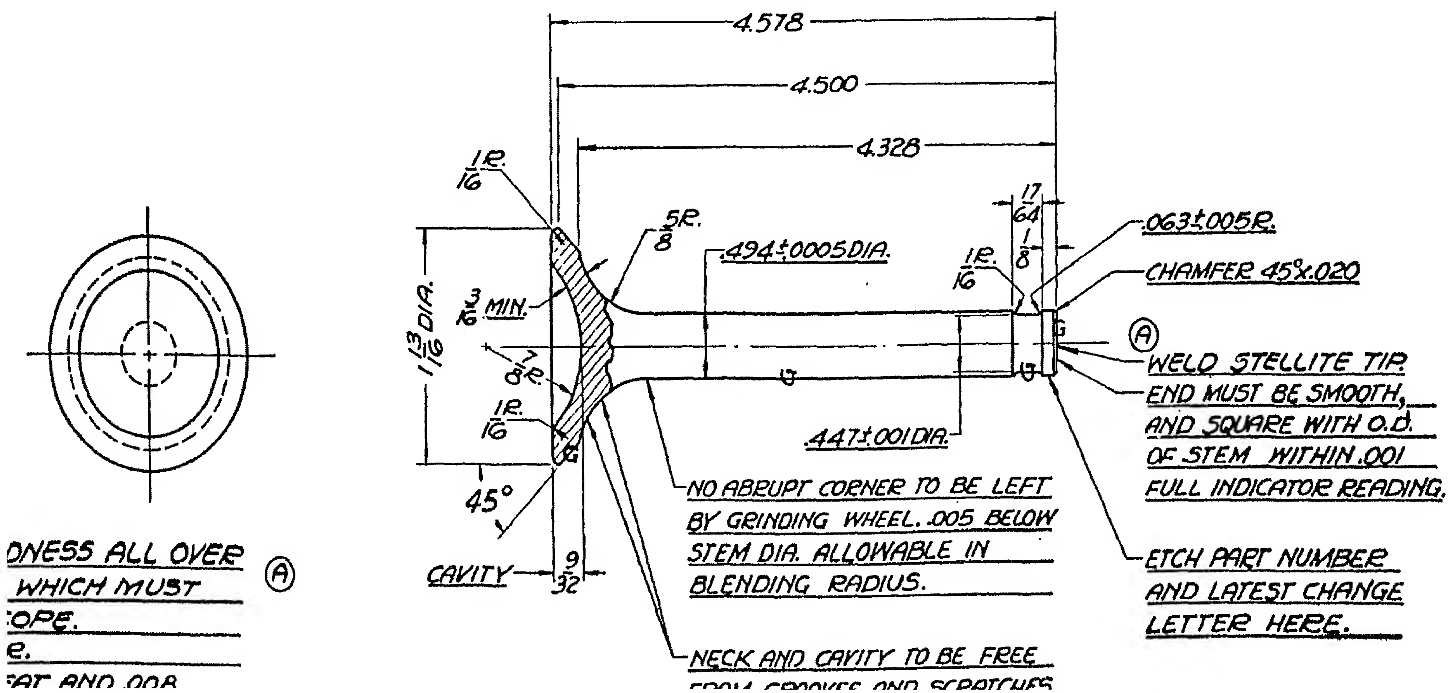


FIG. 15-16. Ranger, 6-440 C-5, Six Cylinder, Inverted, In-Line Engine. (*Ranger Aircraft Engine, Division of Fairchild Engine and Airplane Corporation.*)

ALT NO	LET	ALTERATION [redacted]	DATE	CKR.
1733	A	STELLITE TIP AND HARDNESS NOTE ADDED:	7-17-40	gow



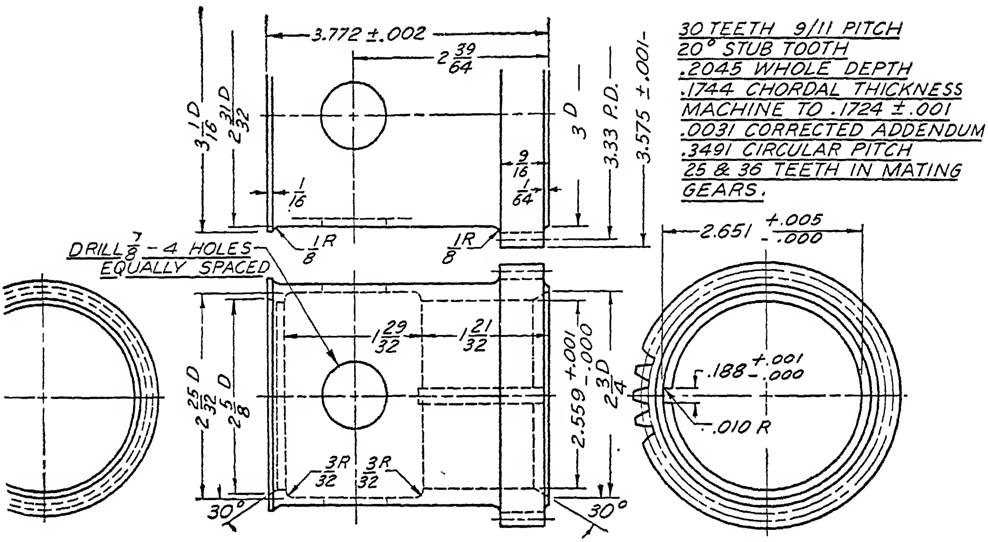


Fig. 15-18. Crankshaft Gear. Prob. 15-20.

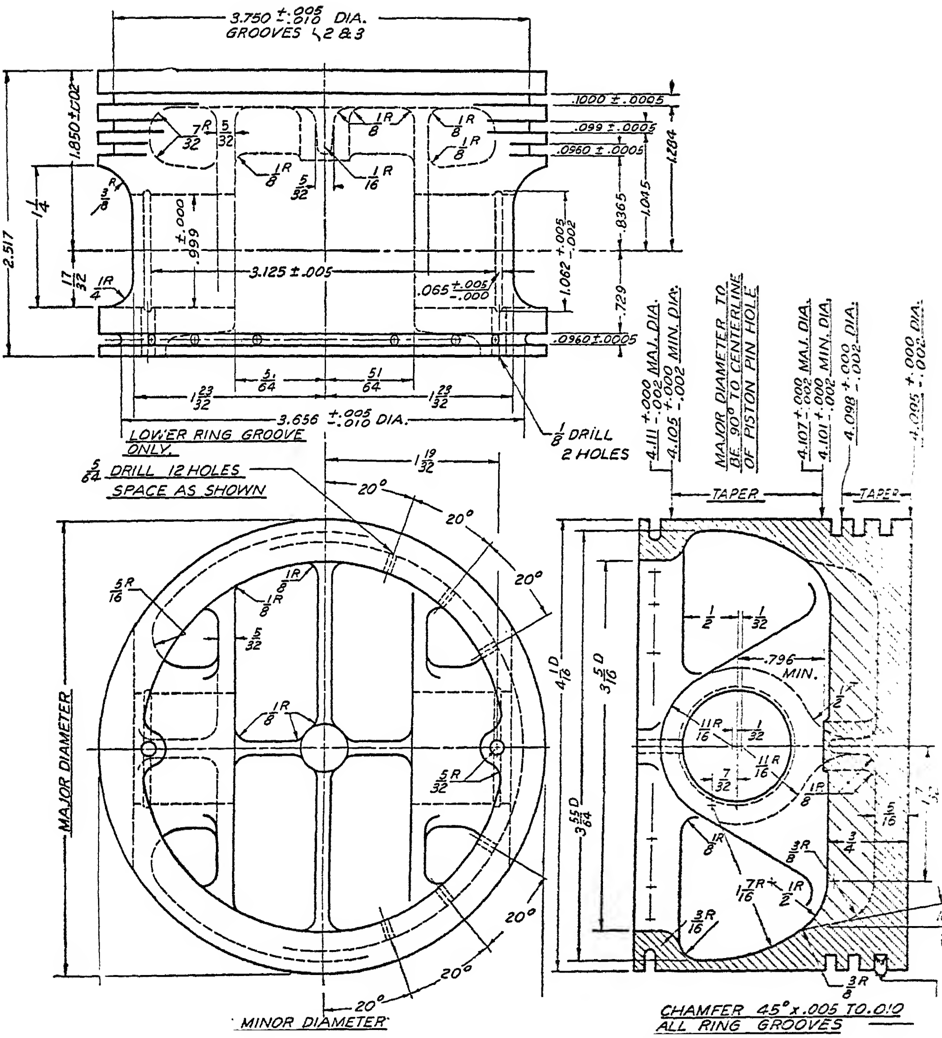


FIG. 15-19. Piston. Prob. 15-21.

CHAPTER XVI

GRAPHIC CHARTS

16–1. Graphic charts and diagrams have become important as a means of representing comparative quantities, variable conditions, engineering computations, formulas and data of various kinds. The effectiveness of graphic presentation is evident in Fig. 16–1 which illustrates the comparative airplane performance between constant speed, two position controllable, and fixed pitch propellers. The drawing of curves or charts presents little difficulty if a few basic principles are understood.

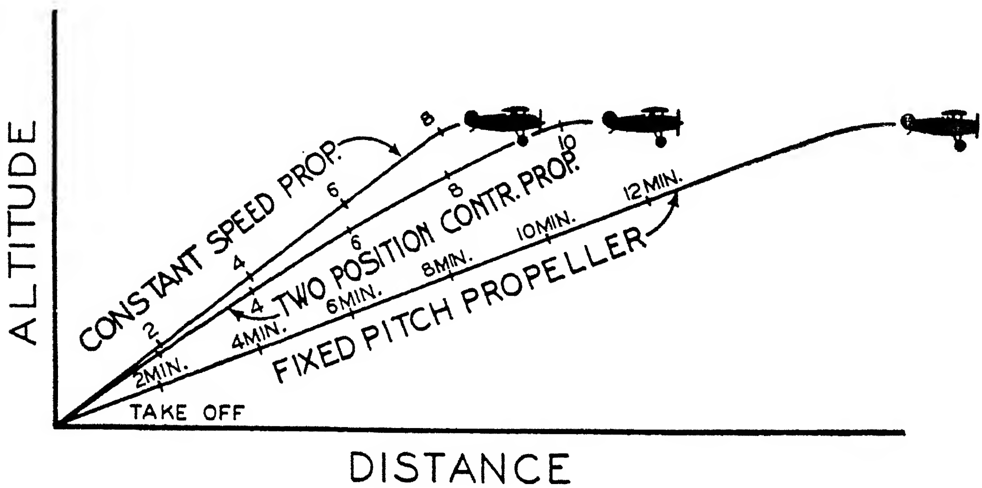


FIG. 16–1. Graphic Chart Comparison. (Hamilton Standard Propeller. Division of United Aircraft Corporation.)

16–2. Aeronautical graphic charts include many of the regular charts for the results of material testing, and general engineering test results, as well as performance curves for aviation engines, strength curves for aircraft elements, an unlimited number of curves for aerodynamics to show results of tests, calculations, variations and comparisons, changing effects of different factors, and design and performance of various parts.

The general classification of types of charts which follows is from the author's *Drafting for Engineers* where they are illustrated and described.

(1) Rectilinear Charts made up of coordinates equally or unequally spaced. Used for computations, formulas, comparative tabulation, etc.

(2) Logarithmic Charts having logarithmic spacing in both directions.

(3) Semi-logarithmic Charts with logarithmic spacing in one direction, equal spacing in the other.

(4) Polar and Circular Charts.

(5) Nomographs or Alignment Charts.

(6) Map and Distribution Charts.

(7) Organization Charts, Flow Sheets, etc.

(8) Pictorial Charts.

(9) Trilinear Charts.

(10) Miscellaneous and Special Charts.

16–3. Graphic chart paper may be obtained in ready-ruled forms which can be adapted to almost any requirements. Ordinary equal spaced ruling is 5, 10, or 20 divisions to the inch for decimal plotting and 4, 6, 8, and 16 divisions to the inch for fractional plotting. Many other rulings are available as logarithmic, semi-logarithmic, time ruling for hours, days, weeks, months, etc., circular ruling for polar coordinates or percentages, etc.

16–4. To Draw a Rectilinear Chart (Fig. 16–2). — The origin or starting point is generally located at the lower left-hand corner of the chart but may be some other place if the character of the data makes it necessary.

First assemble the data, decide upon the form of the chart, select suitable scales, plot the points and draw the curve. The curve of Fig. 16–2 shows the time to climb for a light plane. At sea level the plane climbs at the rate of 700 feet per minute and has a service ceiling of 15,000 feet. The time to climb for each 1000 feet is given in minutes in the table.

Time		Time		Time	
1st 1000 Ft.	1.5	6th 1000 Ft.	2.1	11th 1000 Ft.	3.6
2nd	1.6	7th	2.3	12th	4.2
3rd	1.7	8th	2.5	13th	5.0
4th	1.8	9th	2.8	14th	6.3
5th	1.9	10th	3.1	15th	8.3

The time to climb is laid off vertically at the left side and the altitude is laid off from left to right. The values have been plotted and the curve which has been drawn through the points shows the rapid increase in time to climb as the service ceiling is approached. The first 1000 feet takes 1.5 minutes, the last 1000 feet takes 8.3 minutes and the total climb of 15,000 feet takes 48.7 minutes. This is all clearly shown by the curve.

16–5. The character of a curve will depend upon its derivation (Fig. 16–3). For a mathematical equation the curve will be smooth and pass through all the points (Fig. 16–3 at A and B). For experimental values the curve may be straight as at C or curved as at D, but in both cases the sum of the distances of

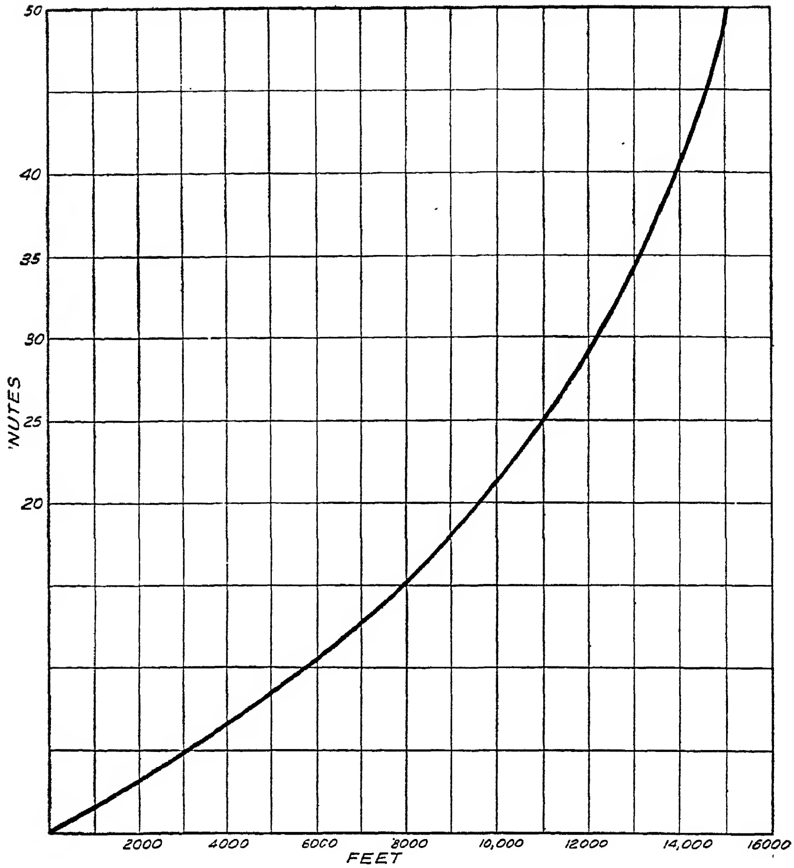


FIG. 16–2. Rectilinear Chart. Time to Climb.

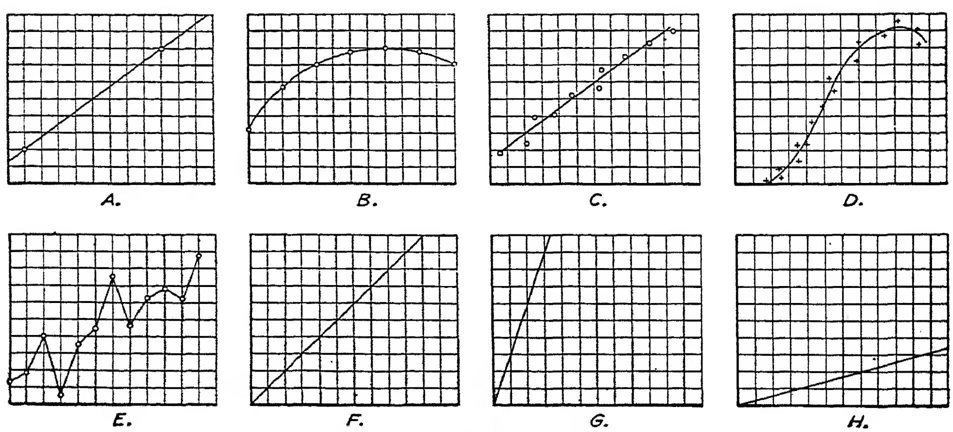


FIG. 16–3. Chart Variations.

the points above the curve should be equal to the sum of the distances below the curve. For a record of facts, or a series of actual numbers as temperatures, costs, etc., the points should be connected by straight lines as at E. The choice of scales will affect the appearance and ease of reading a curve or chart. The *ideal*, if not in conflict with other results, is a 45° line as at F. By variations in the scales the data represented at F could be shown *steep* as at G or *flat* as at H.

16–6. Standards for Graphical Presentation. — A preliminary report of a Joint Committee on Standards for Graphic Presentation, sponsored by the American Society of Mechanical Engineers, has made the following suggestions:

"1. The general arrangement of a diagram should proceed from left to right.

"2. Where possible represent quantities by linear magnitudes, as areas or volumes are more likely to be misinterpreted.

"3. For a curve the vertical scale, whenever practicable, should be so selected that the zero line will appear on the diagram.

"4. If the zero line of the vertical scale will not normally appear on the curve diagram, the zero line should be shown by the use of a horizontal break in the diagram.

"5. The zero lines of the scales for a curve should be sharply distinguished from the other coordinate lines.

"6. For curves having a scale representing percentages, it is usually desirable to emphasize in some distinctive way the 100 per cent line or other line used as a basis of comparison.

"7. When the scale of a diagram refers to dates, and the period represented is not a complete unit, it is better not to emphasize the first and last ordinates, since such a diagram does not represent the beginning or end of time.

"8. When curves are drawn on logarithmic coordinates, the limiting lines of the diagram should each be at some power of ten on the logarithmic scales.

"9. It is advisable not to show any more coordinate lines than necessary to guide the eye in reading the diagram.

"10. The curve lines of a diagram should be sharply distinguished from the ruling.

"11. In curves representing a series of observations, it is advisable, whenever possible, to indicate clearly on the diagram all the points representing the separate observations.

"12. The horizontal scale for curves should usually read from left to right and the vertical scale from bottom to top.

"13. Figures for the scales of a diagram should be placed at the left and at the bottom or along the respective axes.

"14. It is often desirable to include in the diagram the numerical data or formulae represented.

"15. If numerical data are not included in the diagram it is desirable to give the data in tabular form accompanying the diagram.

"16. All lettering and all figures on a diagram should be placed so as to be easily read from the base as the bottom, or from the right-hand edge of the diagram as the bottom.

"17. The title of a diagram should be made as clear and complete as possible. Subtitles or descriptions should be added if necessary to insure clearness."

16–7. Bar charts or barographs are used to represent quantities or amounts by means of lines, proportional in length to the amounts. Such lines or bars are made any convenient width and may be drawn horizontally (Fig. 16–4) or vertically.

A percentage or a component-part chart may be drawn as a 100 per cent bar chart (Fig. 16–5) or as a circle or "pie" chart (Fig. 16–6).

16–8. Titles and Notes. — Graphic charts should have a definite title and such notes as are necessary to insure the correct reading of the chart. Scales should indicate the kinds of units. When more than one curve is shown they should be labeled if necessary for identification and different kinds or weights of lines may be used. Sometimes tabulated data is included.

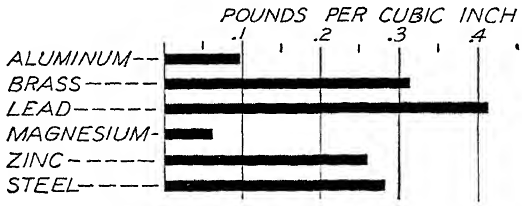
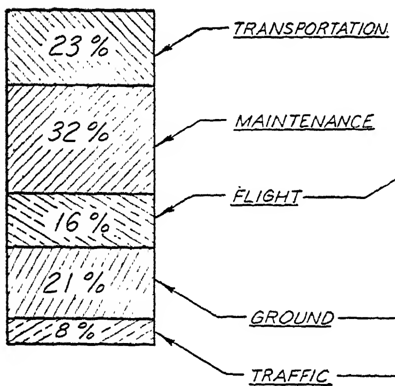


Fig. 16–4. A Bar Chart.



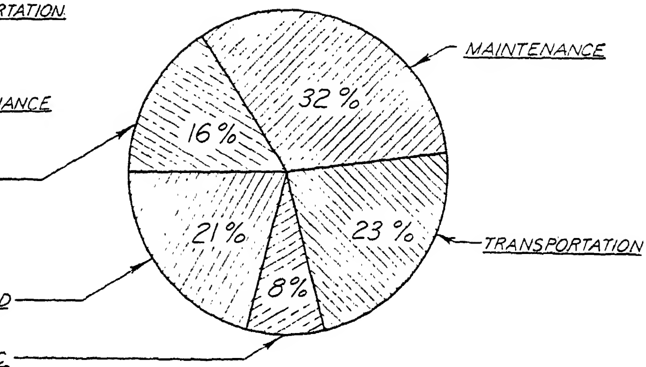


Fig. 16–5. A 100% Bar Chart

Fig. 16–6. A " Pie " Chart.

16–9. A performance chart for a Lycoming Aviation Engine is shown in Fig. 16–7 and is self explanatory. The chart (Fig. 16–8) showing power required and power available illustrates the use of two kinds of lines and two sets of curves. The full lines show the hp. required and available at an altitude of 5000 feet and the dash lines show the same information at sea level. At sea level the maximum speed is seen to be 89 miles per hour as indicated by the intersection of the curves. This has been reduced to 85 miles per hour at 5000 feet.

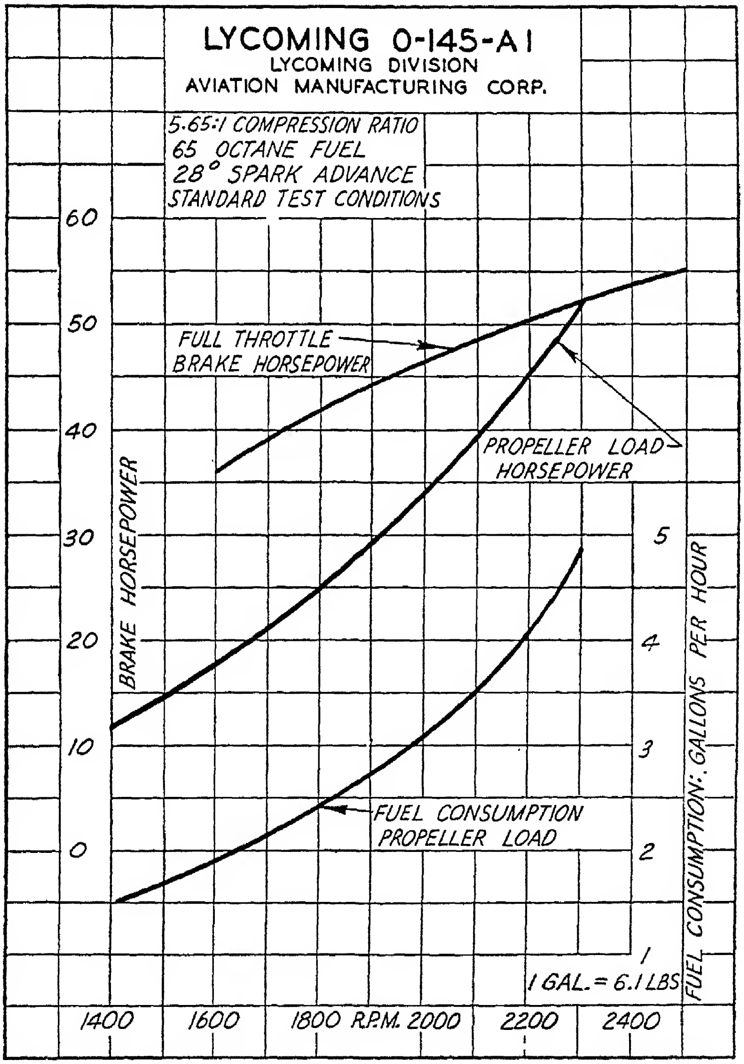


Fig. 16–7. Performance Chart.

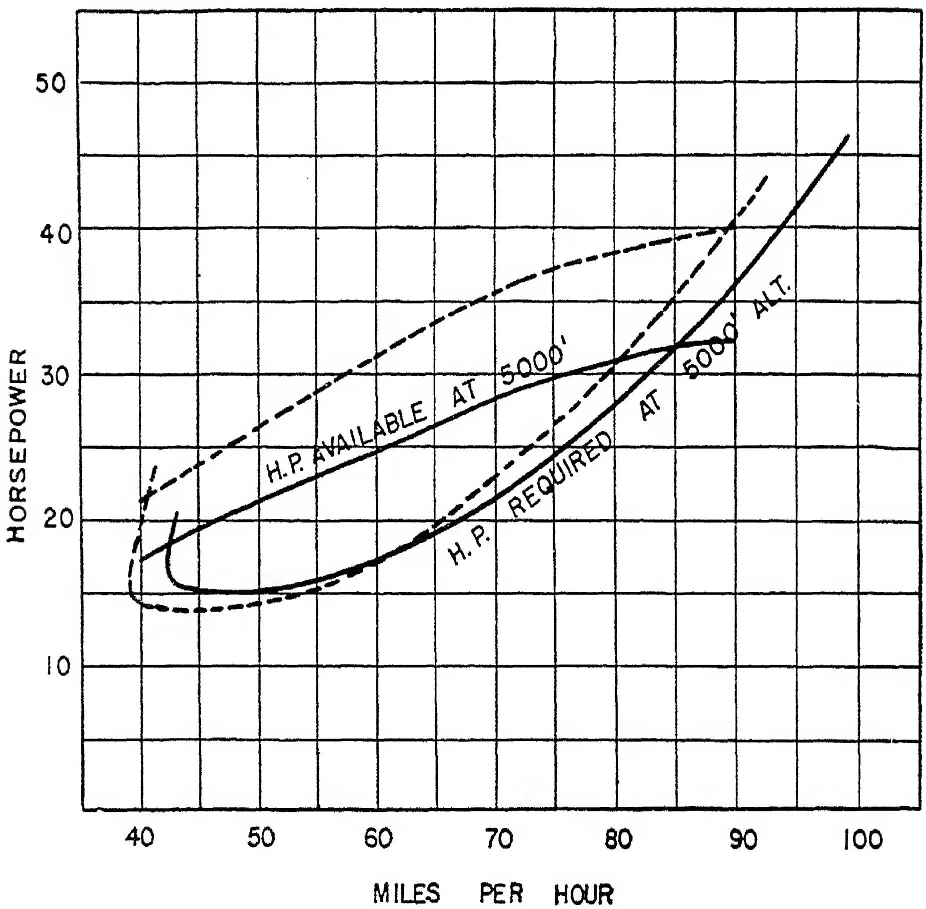


FIG. 16–8. Comparison Chart. (*Civil Aeronautics Bulletin, No. 26.*)

CHAPTER XVII

DATA AND REFERENCE MATERIAL

17–1. Computation of Weights. — Weight is a most important factor in connection with airplane parts. The weights of parts are computed before they are made and actual weights are determined and recorded after manufacture.

The computation of weights in general is based upon the theory of dimensioning as treated in Chapter XI, by considering the part to be made up of elementary type solids. The slide rule can be used to make approximate calculations from drawings for estimating purposes. Tables of weights of rods, tubes, sheets, etc., of different materials in different units, as well as in pounds per cubic inch should be available for convenience in calculating weights. Some average weights of materials are given in Table 17–1.

TABLE 17–1. WEIGHTS OF METALS (Pounds per cubic inch)

Aluminum, Wrought	.0979	Lead	.411
Cast	.0925	Magnesium	.063
Brass, Cast or Sheet	.313	Nickel	.320
Naval Cast or Rolled	.304	Steel	.284
Copper	.318	Zinc	.260

To find the weight of the wrought aluminum piece of Fig. 17–1: Compute the total volume in cubic inches and multiply by the weight per cubic inch. The flanged bushing shown may be divided into four parts as tabulated in which *A* and *B* are called plus (+) volumes, and *C* and *D* minus (−) or negative volumes. The four corners cut off are considered together to form a rectangular plate.

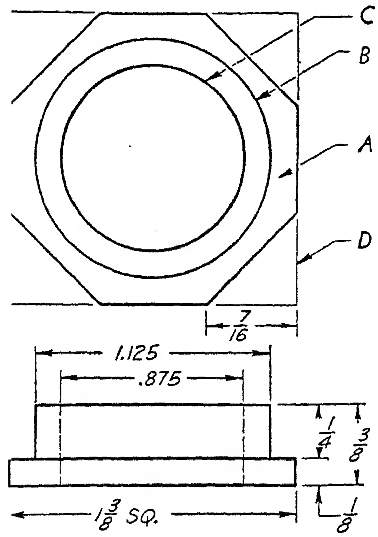


FIG. 17–1. Computation of Weights.

Designation	Part	Dimensions	Vol. Cu. In. +	Vol. Cu. In. −
A	Square Plate	$1\frac{3}{8} \times 1\frac{3}{8} \times \frac{1}{8}$	.236	
B	Cylinder	$\frac{\pi + 1.125^2}{4} \times \frac{1}{4}$	.249	
C	Cylinder	$\frac{\pi \times .875^2}{4} \times \frac{3}{8}$		.225
D	Plate	$\frac{7}{16} \times \frac{7}{8} \times \frac{1}{8}$		.048

$$(A + B) - (C + D) = \text{Net volume}$$
$$.485 - .273 = .212 \text{ Cu. In.}$$
$$\text{Vol.} \times \text{wt. per cu. in.} = \text{total weight}$$
$$.212 \times .0979 = .208 \text{ Lb.}$$

The net volume is .212 cu. in. and the weight if made of wrought aluminum is .212 × .0979 = .208 pounds.

TABLE 17-2

(North American Aviation, Inc.)

SIZES OF TWIST DRILLS FROM ½ INCH TO NO. 80 WITH DECIMAL EQUIVALENTS

Size	Decimal Equiv.	Size	Decimal Equiv.	Size	Decimal Equiv.	Size	Decimal Equiv.
1/2	.5000	G	.2600	23	.1540	1/16	.0625
31/64	.4844	F	.2570	24	.1520	53	.0595
15/32	.4687	1/4	.2500	25	.1495	54	.0550
29/64	.4531	D	.2460	26	.1470	55	.0520
7/16	.4375	C	.2420	27	.1440	3/64	.0469
27/64	.4219	B	.2380	9/64	.1406	56	.0465
Z	.4130	15/64	.2344	28	.1405	57	.0430
13/32	.4062	A	.2340	29	.1360	58	.0420
Y	.4040	1	.2280	30	.1285	59	.0410
X	.3970	2	.2210	1/8	.1250	60	.0400
25/64	.3906	7/32	.2187	31	.1200	61	.0390
W	.3860	3	.2130	32	.1160	62	.0380
V	.3770	4	.2090	33	.1130	63	.0370
3/8	.3750	5	.2055	34	.1110	64	.0360
U	.3680	6	.2040	35	.1100	65	.0350
23/64	.3594	13/64	.2031	7/64	.1094	66	.0330
T	.3580	7	.2010	36	.1065	67	.0320
S	.3480	8	.1990	37	.1040	1/32	.0313
11/32	.3437	9	.1960	38	.1015	68	.0310
R	.3390	10	.1935	39	.0995	69	.0292
Q	.3320	11	.1910	40	.0980	70	.0280
21/64	.3281	12	.1890	41	.0960	71	.0260
P	.3230	3/16	.1875	3/32	.0937	72	.0250
O	.3160	13	.1850	42	.0935	73	.0240
5/16	.3125	14	.1820	43	.0890	74	.0225
N	.3020	15	.1800	44	.0860	75	.0210
19/64	.2969	16	.1770	45	.0820	76	.0200
M	.2950	17	.1730	46	.0810	77	.0180
L	.2900	11/64	.1719	47	.0785	78	.0160
9/32	.2812	18	.1695	5/64	.0781	1/64	.0156
K	.2810	19	.1660	48	.0760	79	.0145
J	.2770	20	.1610	49	.0730	80	.0135
I	.2720	21	.1590	50	.0700		
H	.2660	22	.1570	51	.0670		
17/64	.2656	5/32	.1562	52	.0635		

Above ½ inch, drills increase by 1/64 ths. to 1½ inches.

Note:

The minimum tolerances that may be maintained in holes drilled in conjunction with suitable drill jig guide bushings are as follows:

#60 to #30	tolerance .002	#½ to ¾	tolerance .005
#30 to #1	tolerance .003	#¾ to 1	tolerance .007
#¼ to ½	tolerance .004	#1 to 2	tolerance .010

TABLE 17-3. Wire, Sheet Metal, and Tube Gages.

1. B.S. Brown and Sharpe. American Standard Wire. Non-ferrous sheet and wire. (Aluminum and copper alloys.)
2. N.W. National Wire. Roebling. Washburn and Moen, American Steel & Wire. (All bare, galvanized and annealed steel and iron wire. All tinned steel wire.)
3. M.W. Music Wire. Spring wire (piano wire).
4. U.S. United States Standard. (All sheet steel, tinned and terne plate and galvanized iron.)
5. B.W. Birmingham Wire. Stubbs Iron Wire Gage. (All seamless tubing, both ferrous and non-ferrous, and spring steel.)

Gage No.	1 B. & S.	2 N.W.	3 M.W.	4 U.S.	5 B.W.	Gage No.
00000000	....	....	....	....	....	00000000
0000000	....	.4900	....	....	....	0000000
000000	....	.4615	.004	.46875	....	000000
00000	....	.4305	.005	.4375	....	00000
0000	.460	.3938	.006	.40625	.454	0000
000	.40964	.3625	.007	.375	.425	000
00	.3648	.3310	.008	.34375	.380	00
0	.32486	.3065	.009	.3125	.340	0
1	.2893	.2830	.010	.28125	.300	1
2	.25763	.2625	.011	.265625	.284	2
3	.22942	.2437	.012	.250	.259	3
4	.20431	.2253	.013	.234375	.238	4
5	.18194	.2070	.014	.21875	.220	5
6	.16202	.1920	.016	.203125	.203	6
7	.14428	.1770	.018	.1875	.180	7
8	.12849	.1620	.020	.171875	.165	8
9	.11443	.1483	.022	.15625	.148	9
10	.10189	.1350	.024	.140625	.134	10
11	.090742	.1205	.026	.125	.120	11
12	.080808	.1055	.029	.109375	.109	12
13	.071961	.0915	.031	.09375	.095	13
14	.064084	.0800	.033	.078125	.083	14
15	.057068	.0720	.035	.0703125	.072	15
16	.05082	.0625	.037	.0625	.065	16
17	.045257	.0540	.039	.05625	.058	17
18	.040303	.0475	.041	.050	.049	18
19	.03589	.0410	.043	.04375	.042	19
20	.031961	.0348	.045	.0375	.035	20
21	.028462	.0317	.047	.034375	.032	21
22	.025347	.0286	.049	.03125	.028	22
23	.022571	.0258	.051	.028125	.025	23
24	.0201	.0230	.055	.025	.022	24
25	.0179	.0204	.059	.021875	.020	25
26	.01594	.0181	.063	.01875	.018	26
27	.014195	.0173	.067	.0171875	.016	27
28	.012641	.0162	.071	.015625	.014	28
29	.011257	.0150	.075	.0140625	.013	29
30	.010025	.0140	.080	.0125	.012	30
31	.008928	.0132	.085	.0109375	.010	31
32	.00795	.0128	.090	.01015625	.009	32
33	.00708	.0118	.095	.009375	.008	33
34	.006304	.0104	....	.00859375	.007	34
35	.005614	.0095	....	.0078125	.005	35
36	.005	.0090	....	.00703125	.004	36
37	.004453	.0085	....	.006640625	....	37
38	.003965	.0080	....	.00625	....	38
39	.003531	.0075	....	....	....	39
40	.003144	.0070	....	....	....	40

TABLE 17-4

HOLE SIZES FOR BOLTS, SCREWS, RIVETS, AND PINS IN METAL

(North American Aviation, Inc.)

Size	Rivets-Drill	Cotter Pin-Drill	Flat Head Pin-Drill	Screw Bolt Clearance Hole	Reamer Drill	
					Drill	Ream
1/16(.0625)	#52(.0635)	#48(.076)				
#2(.086)				#43(.089)		
3/32(.09375)	#40(.098)	#36(.106)				
#3(.099)				#37(.104)		
#4(.112)				#31(.120)		
1/8(.125)	#30(.1285)	#28(.1405)	1/8(.125)			
#6(.138)				#27(.144)		
5/32(.15625)	#21(.159)	#16(.177)				
#8(.164)				#18(.1695		
3/16(.1875)	#11(.191)	#4(.209)	3/16(.1875)			
#10(.190)				#10(.1935)	14(.182)	.189 + .0005 − .001
1/4(.250)	1/4(.250)	I (.272)	1/4(.250)	F (.257)	C (.242)	.250 + .0005 − .001
5/16(.3125)	O (.316)		O (.316)	O (.316)	N (.302)	.3125 + .0005 − .001
3/8(.275)	V (.377)		V (.377)	V (.377)	23/64(.359)	.375 + .0005 − .001
↑ To 2″ Dia. ↓					Drill 1/64 Under Nominal Dia. to 1¾, over 1¾, bore rather than drill.	All Diameters +.0005 −.001

TABLE 17-5. MINIMUM CLEARANCE ALLOWANCE FOR WRENCH MOVEMENTS THROUGH 60° AND SOCKET WRENCH DIAMETERS

Size	Aircraft Nuts			
	Across Flats	Min. A	Min. B	Bore for Socket Wrench
#10	3/8	3/8	5/8	11/16
1/4	7/16	3/8	5/8	11/16
5/16	1/2	7/16	3/4	13/16
3/8	9/16	1/2	7/8	15/16
9/16	5/8	9/16	1	1 1/16
1/2	3/4	11/16	1 1/8	1 3/16
9/16	7/8	13/16	1 1/4	1 5/16
5/8	15/16	7/8	1 1/2	1 5/8
3/4	1 1/16	1	1 5/8	1 3/4
7/8	1 1/4	1 1/8	1 7/8	2
1	1 7/16	1 3/8	2 1/8	2 1/4

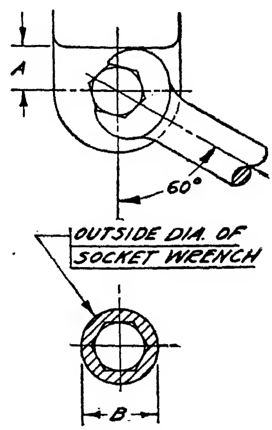


FIG. 17-2.

TABLE 17-6. Approximate Radii for 90° Cold Bend Aluminum and Aluminum Alloy Sheet (Aluminum Company of America)

Minimum permissible radius varies with nature of forming operation, type of forming equipment and design and condition of tools. Minimum working radius for given material or hardest alloy and temper for a given radius can be ascertained only by actual trial under contemplated conditions of fabrication.

Alloy and Temper	Bend Classification[2]	Alloy and Temper	Bend Classification[2]
2S-O	A	24S-O (3)	B
2S-¼H	B	24S-T (1) (3)	J
2S-½H	B	24S-RT (3)	K
2S-¾H	D		
2S-H	F	52S-O	A
		52S-¼H	C
3S-O	A	52S-½H	D
3S-¼H	B	52S-¾H	F
2S-½H	C	52S-H	G
3S-¾H	E		
3S-H	G	53S-O	A
		53S-W	F
17S-O (3)	B	53S-T	G
17S-T (1) (3)	H		
		61S-O	B
		61S-W	E
		61S-T	F

[1]Immediately after quenching, these alloys can be formed over appreciably smaller radii.
[2]For corresponding bend radii see table below.
[3]Alclad 17S and Alclad 24S can be bent over slightly smaller radii than the corresponding tempers of the uncoated alloy.

Radii Required for 90° Bend in Terms of Thickness, (Aluminum Company of America)

		Approximate Thickness					
	B & S Gage	26	20	14	8	5	2
	Inch	0.016	0.032	0.064	0.128	0.182	0.258
	Inch	1/64	1/32	1/16	1/8	3/16	1/4
Bend Classification	A	0	0	0	0	0	0
	B	0	0	0	0	0–1t	0–1t
	C	0	0	0	0–1t	0–1t	½t–1½t
	D	0	0	0–1t	½t–1½t	1t–2t	1½t–3t
	E	0–1t	0–1t	½t–1½t	1t–2t	1½t–3t	2t–4t
	F	0–1t	½t–1½t	1t –2t	1½t–3t	2t–4t	2t–4t
	G	½t–1½t	1t–2t	1½t–3t	2t–4t	3t–5t	4t–6t
	H	1t–2t	1½t–3t	2t–4t	3t–5t	4t–6t	4t–6t
	J	1½t–3t	2t–4t	3t–5t	4t–6t	4t–6t	5t–7t
	K	2t–4t	3t–5t	3t–5t	4t–6t	5t–7t	6t–10t

TABLE 17-7. NOMINAL COMPOSITION OF WROUGHT ALUMINUM ALLOYS[1]
(Aluminum Company of America)

Alloy	Per Cent of Alloying Elements — Aluminum and Normal Impurities Constitute Remainder								
	Copper	Silicon	Manganese	Magnesium	Zinc	Nickel	Chromium	Lead	Bismuth
2S	...	...	...	...	....	...	....	...	...
3S	...	...	1.2	...	....	...	....	...	...
11S	5.5	...	...	...	....	...	....	0.5	0.5
14S	4.4	0.8	0.8	0.4	....	...	....	...	...
17S	4.0	...	0.5	0.5	....	...	....	...	...
A17S	2.5	...	...	0.3	....	...	....	...	...
18S	4.0	...	...	0.5	....	2.0	....	...	...
24S	4.5	...	0.6	0.5	....	...	....	...	...
25S	4.5	0.8	0.8	...	....	...	....	...	...
32S	0.9	12.5	...	1.0	....	0.9	....	...	...
A51S	...	1.0	...	0.6	....	...	0.25	...	...
52S	...	...	...	2.5	....	...	0.25	...	...
53S	...	0.7	...	1.3	....	...	0.25	...	...
56S	...	...	0.1	5.2	....	...	0.1	...	...
61S	0.25	0.6	...	1.0	....	...	0.25	...	...
70S	1.0	...	0.7	0.4	10.0	...	....	...	...

[1]Heat-treatment symbols have been omitted since composition does not vary for different heat-treatment practices.

TABLE 17-8. NOMINAL COMPOSITION OF ALUMINUM SAND-CASTING ALLOYS[1]
(Aluminum Company of America)

Alloy	Per Cent of Alloying Elements — Aluminum and Normal Impurities Constitute Remainder						
	Copper	Iron	Silicon	Zinc	Magnesium	Nickel	Manganese
43	....	...	5.0	....	....	...	...
47	....	...	12.5	....	....	...	...
108	4.0	...	3.0	....	....	...	...
112	7.5	1.2	....	2.0	....	...	...
122	10.0	1.2	....	....	0.2	...	...
142	4.0	...	....	....	1.5	2.0	...
195	4.0	...	....	....	....	...	...
212	8.0	1.0	1.2	....	....	...	...
214	....	...	....	....	3.8	...	...
220	....	...	....	....	10.0	...	...
A334	3.0	...	4.0	....	0.3	...	...
355	1.3	...	5.0	....	0.5	...	...
A355	1.4	...	5.0	....	0.5	0.8	0.8
356	....	...	7.0	....	0.3	...	...
645	2.5	1.2	....	11.0	....	...	...

[1]Heat-treatment symbols have been omitted since composition does not vary for different heat-treatment practices.

TABLE 17–9. NOMINAL COMPOSITION OF ALUMINUM PERMANENT-MOLD CASTING ALLOYS[1]
(Aluminum Company of America)

Alloy	Per Cent of Alloying Elements — Aluminum and Normal Impurities Constitute Remainder					
	Copper	Iron	Silicon	Zinc	Magnesium	Nickel
43	...	...	5.0	...	...	...
A108	4.5	...	5.5	...	...	...
B113	7.0	1.2	1.7	...	...	...
C113	7.0	1.2	4.0	2.0	...	...
122	10.0	1.2	...	...	0.2	...
A132	0.8	0.8	12.0	...	1.0	2.5
138	10.0	1.4	4.0	...	0.2	...
142	4.0	...	...	...	1.5	2.0
B195	4.5	...	2.5	...	...	...
A214	...	...	...	1.8	3.8	...
355	1.3	...	5.0	...	0.5	...
356	...	...	7.0	...	0.3	...

[1]Heat-treatment symbols have been omitted since composition does not vary for different heat-treatment practices.

TABLE 17–10. NOMINAL COMPOSITION OF ALUMINUM DIE-CASTING ALLOYS
(Aluminum Company of America)

Alloy	Per Cent of Alloying Elements — Aluminum and Normal Impurities Constitute Remainder			
	Copper	Silicon	Nickel	Magnesium
13	..	12	..	..
43	..	5	..	..
81	7	3	..	..
82	14	5	..	..
83	2	3	..	..
85	4	5	..	..
93	4	2	4	..
218	..	..	..	8

TABLE 17–11. DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH

Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	Fraction	Decimal
1/64	= .015625	17/64	= .265625	33/64	= .515625	49/64	= .765625
1/32	= .03125	9/32	= .28125	17/32	= .53125	25/32	= .78125
3/64	= .046875	19/64	= .296875	35/64	= .546875	51/64	= .796875
1/16	= .0625	5/16	= .3125	9/16	= .5625	13/16	= .8125
5/64	= .078125	21/64	= .328125	37/64	= .578125	53/64	= .828125
3/32	= .09375	11/32	= .34375	19/32	= .59375	27/32	= .84375
7/64	= .109375	23/64	= .359375	39/64	= .609375	55/64	= .859375
1/8	= .125	3/8	= .375	5/8	= .625	7/8	= .875
9/64	= .140625	25/64	= .390625	41/64	= .640625	57/64	= .890625
5/32	= .15625	13/32	= .40625	21/32	= .65625	29/32	= .90625
11/64	= .171875	27/64	= .421875	43/64	= .671875	59/64	= .921875
3/16	= .1875	7/16	= .4375	11/16	= .6875	15/16	= .9375
13/64	= .203125	29/64	= .453125	45/64	= .703125	61/64	= .953125
7/32	= .21875	15/32	= .46875	23/32	= .71875	31/32	= .96875
15/64	= .234375	31/64	= .484375	47/64	= .734375	63/64	= .984375
1/4	= .25	1/2	= .5	3/4	= .75	....	

TABLE 17–12. MINIMUM BEND RADII FOR SHEET METAL
(Curtiss Aeroplane Division, Curtiss-Wright Corporation, Buffalo, New York)

Aluminum Alloys				Steel			Magnesium		
				Stainless		Low Carbon & X-4130 Annealed		Army 11317	Navy M-111
Thickness	24ST and Alclad	24SO and Alclad	** 2S½Hard 3S½Hard	Annealed	½Hard*		Thickness	Cold Bend	Hot Formed
Up to .015	....	....	....	1/32	1/32	....	.012	1/16	1/16
.016	....	....	....	....	....	1/32	.016	3/32	1/16
.020	3/32	3/32	1/32	1/32	1/16	....	.018	1/8	1/16
.025	1/8	3/32	1/32	1/32	....	1/32	.020	1/8	1/16
.030	....	....	....	1/32	1/16	....	.025	3/16	1/16
.031	....	....	....	....	....	1/32	.032	1/4	3/32
.032	1/8	3/32	1/16	....	....	....	.040	5/16	3/32
.038	....	....	....	1/16	....	1/16	.051	3/8	1/8
.040	1/8	3/32	3/32	....	3/32	....	.064	1/2	3/16
.050	....	....	....	1/16	1/8	1/16	.081	5/8	3/16
.051	3/16	3/32	3/32	....	....	....	.102	3/4	1/4
.063	....	....	....	3/32	1/8	1/16	.125	1	5/16
.064	3/16	3/32	1/8	....	....	....	.187	1 1/2	1/2
.078	....	....	....	3/32	....	3/32	.250	2	5/8
.081	5/16	1/8	3/16	....	....	....	.375	3	1
.094	....	....	....	1/8	....	3/32	....	....	....
.102	7/16	3/16	3/16	....	....	....	....	....	....
.125	....	....	....	3/16	....	1/8	....	....	....
.128	1/2	3/16	....	....	....	....	....	....	....
.156	....	....	....	3/16	....	3/16	....	....	....
3/16	13/16	3/8	3/8	1/4	....	3/16	....	....	....
1/4	1	1/2	1/2	....	....	1/4	....	....	....

* For bends up to 90° only.
** Bend radii for 52S — Same as 2S and 3S.

17–2. The Metric System. — The fundamental units of the metric system are, the meter for length, the gram for weight, and the liter for capacity. Tables 17–14 and 17–13 give length equivalents of fractions of an inch and millimeters.

English and metric equivalents of some of the units in most common use are as follows:

1 Millimeter (mm.) = .03937 inch.
1 Centimeter (cm.) = .3937 inch.
1 Meter (m.) = 39.37 inches = 3.2803 feet.
1 Kilometer (km.) = 39370 inches = 3280.3 feet.
1 Inch = 25.40 mm. = 2.540 cm. = .02540
1 Foot = 304.80 mm. = 30.480 cm. = .30480 m.
1 Sq. cm. = .155 sq. in. 1 sq. in. = 6.452 sq. cm.
1 Sq. m. = 10.764 sq. ft. 1 sq. ft. = .0929 sq. m.

1 Gram (g.) = .03527 oz. av.
1 Kilogram (Kg.) = 35.27 oz. av. = 2.2046 lbs. av.
1 Ton (metric ton = 1000 Kg.) = 2204.6 lbs. av.
1 Pound (avoirdupois) = 453.592 grams.
1 Liter (l.) = 1000 cubic centimeters (c.c.).
1 Liter = 1.05668 U.S. Liquid quarts = 61.023 cu. in. = .0353 cu. ft.
1 Cu. in. = 16.387 c.c. = .016 liter.
1 Cu. ft. = 283170 c.c. = 283.170 liters.

TABLE 17-9. NOMINAL COMPOSITION OF ALUMINUM PERMANENT-MOLD CASTING ALLOYS[1]

(Aluminum Company of America)

Alloy	Per Cent of Alloying Elements — Aluminum and Normal Impurities Constitute Remainder					
	Copper	Iron	Silicon	Zinc	Magnesium	Nickel
43	...	...	5.0	...	...	...
A108	4.5	...	5.5	...	...	...
B113	7.0	1.2	1.7	...	...	...
C113	7.0	1.2	4.0	2.0	...	...
122	10.0	1.2	...	...	0.2	...
A132	0.8	0.8	12.0	...	1.0	2.5
138	10.0	1.4	4.0	...	0.2	...
142	4.0	...	...	...	1.5	2.0
B195	4.5	...	2.5	...	...	...
A214	...	...	...	1.8	3.8	...
355	1.3	...	5.0	...	0.5	...
356	...	...	7.0	...	0.3	...

[1]Heat-treatment symbols have been omitted since composition does not vary for different heat-treatment practices.

TABLE 17-10. NOMINAL COMPOSITION OF ALUMINUM DIE-CASTING ALLOYS

(Aluminum Company of America)

Alloy	Per Cent of Alloying Elements — Aluminum and Normal Impurities Constitute Remainder			
	Copper	Silicon	Nickel	Magnesium
13	..	12	..	..
43	..	5	..	..
81	7	3	..	..
82	14	5	..	..
83	2	3	..	..
85	4	5	..	..
93	4	2	4	..
218	..	..	..	8

TABLE 17-11. DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH

Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	Fraction	Decimal
1/64	= .015625	17/64	= .265625	33/64	= .515625	49/64	= .765625
1/32	= .03125	9/32	= .28125	17/32	= .53125	25/32	= .78125
3/64	= .046875	19/64	= .296875	35/64	= .546875	51/64	= .796875
1/16	= .0625	5/16	= .3125	9/16	= .5625	13/16	= .8125
5/64	= .078125	21/64	= .328125	37/64	= .578125	53/64	= .828125
3/32	= .09375	11/32	= .34375	19/32	= .59375	27/32	= .84375
7/64	= .109375	23/64	= .359375	39/64	= .609375	55/64	= .859375
1/8	= .125	3/8	= .375	5/8	= .625	7/8	= .875
9/64	= .140625	25/64	= .390625	41/64	= .640625	57/64	= .890625
5/32	= .15625	13/32	= .40625	21/32	= .65625	29/32	= .90625
11/64	= .171875	27/64	= .421875	43/64	= .671875	59/64	= .921875
3/16	= .1875	7/16	= .4375	11/16	= .6875	15/16	= .9375
13/64	= .203125	29/64	= .453125	45/64	= .703125	61/64	= .953125
7/32	= .21875	15/32	= .46875	23/32	= .71875	31/32	= .96875
15/64	= .234375	31/64	= .484375	47/64	= .734375	63/64	= .984375
1/4	= .25	1/2	= .5	3/4	= .75	....	

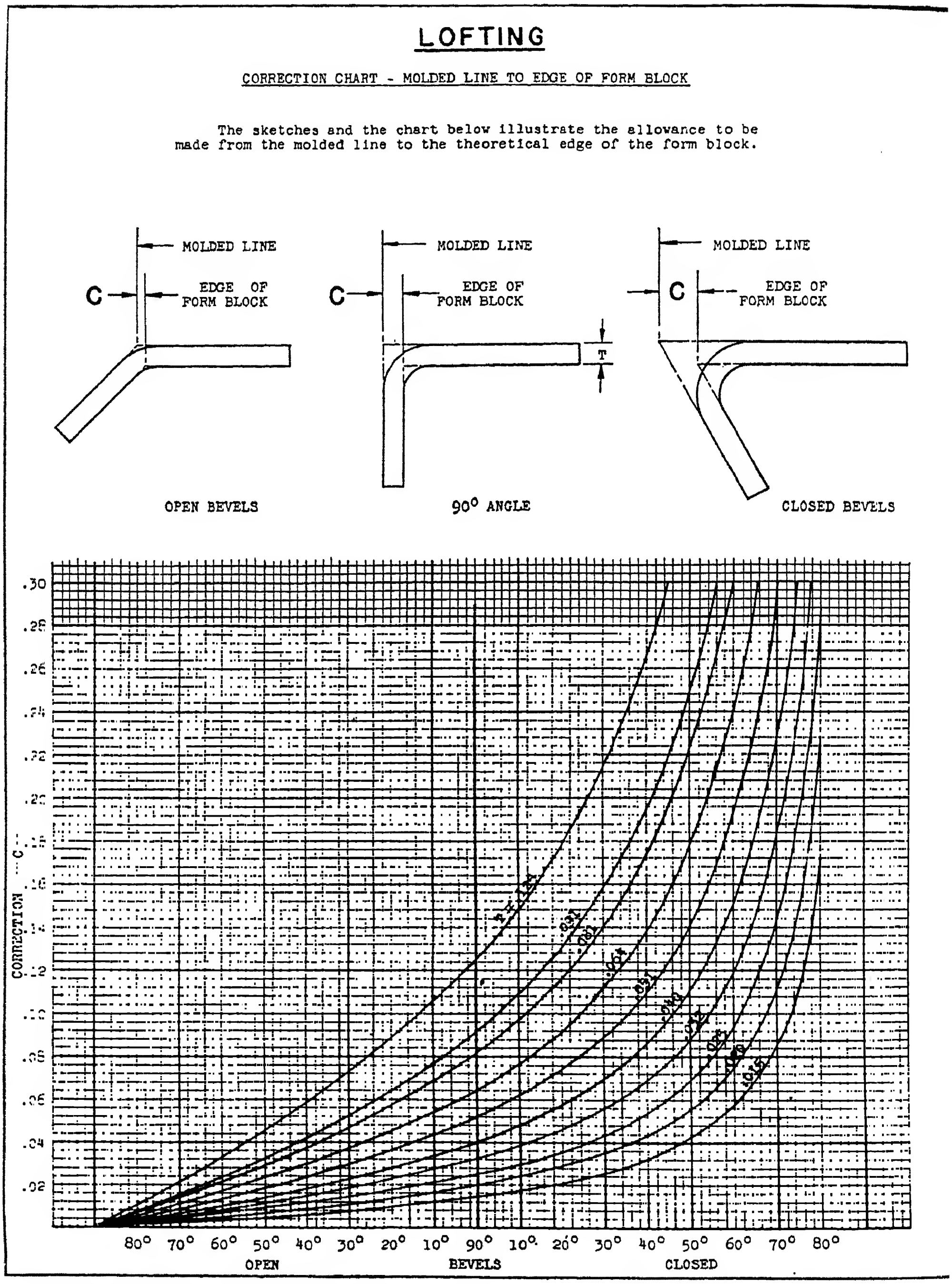


FIG. 17–3. Lofting. (Courtesy of the Curtiss Aeroplane Division, Curtiss-Wright Corporation, Buffalo, N. Y.)

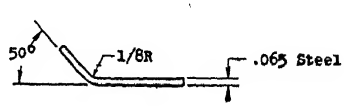
TABLE 17-15. BEND ALLOWANCES
(Courtesy of the Curtiss Aeroplane Division, Curtiss-Wright Corporation, Buffalo, N. Y.)

BEND ALLOWANCES

SHEET METAL BEND ALLOWANCES
PER DEGREE OF BEND

Bend Radius	ALUMINUM ALLOYS								STEEL						
	Stock Thickness														
	.022	.032	.040	.051	.064	.091	.128	.187	.028	.035	.049	.065	.095	.120	.187
	Bend Allowance Per One Degree														
1/32	.00072	.00079	.00086	.00094	.00104	.00125	.00154	.00200	.00076	.00082	.00093	.00105	.00129	.00148	.00200
1/16	.00126	.00135	.00140	.00149	.00159	.00180	.00209	.00255	.00131	.00136	.00147	.00160	.00183	.00203	.00255
3/32	.00180	.00188	.00195	.00203	.00213	.00234	.00263	.00309	.00185	.00191	.00202	.00214	.00238	.00257	.00309
1/8	.00235	.00243	.00249	.00258	.00268	.00289	.00317	.00364	.00240	.00245	.00256	.00269	.00292	.00311	.00364
5/32	.00290	.00297	.00304	.00312	.00322	.00343	.00372	.00418	.00294	.00300	.00311	.00323	.00346	.00366	.00418
3/16	.00344	.00352	.00358	.00367	.00377	.00398	.00426	.00473	.00349	.00354	.00365	.00378	.00401	.00420	.00473
7/32	.00398	.00406	.00412	.00421	.00431	.00452	.00481	.00527	.00403	.00409	.00419	.00432	.00455	.00475	.00527
1/4	.00454	.00461	.00467	.00476	.00486	.00507	.00535	.00582	.00458	.00463	.00474	.00487	.00510	.00529	.00582
9/32	.00507	.00515	.00521	.00530	.00540	.00561	.00590	.00636	.00512	.00517	.00528	.00541	.00564	.00584	.00636
5/16	.00562	.00570	.00576	.00584	.00595	.00616	.00644	.00691	.00567	.00572	.00583	.00596	.00619	.00638	.00691
11/32	.00616	.00624	.00630	.00639	.00649	.00670	.00699	.00745	.00620	.00626	.00637	.00650	.00673	.00693	.00745
3/8	.00671	.00679	.00685	.00693	.00704	.00725	.00753	.00800	.00675	.00681	.00692	.00705	.00728	.00747	.00800
13/32	.00725	.00733	.00739	.00748	.00758	.00779	.00808	.00854	.00730	.00735	.00746	.00759	.00782	.00802	.00854
7/16	.00780	.00787	.00794	.00802	.00812	.00834	.00862	.00908	.00784	.00790	.00801	.00813	.00837	.00856	.00908
15/32	.00834	.00842	.00848	.00857	.00867	.00888	.00917	.00963	.00839	.00844	.00855	.00868	.00891	.00911	.00963
1/2	.00889	.00896	.00903	.00911	.00921	.00943	.00971	.01017	.00893	.00899	.00910	.00922	.00946	.00965	.01017
17/32	.00943	.00951	.00957	.00966	.00976	.00997	.01025	.01072	.00948	.00953	.00964	.00977	.01000	.01019	.01072
9/16	.00998	.01005	.01012	.01020	.01030	.01051	.01080	.01126	.01002	.01008	.01019	.01031	.01055	.01074	.01126
19/32	.01051	.01058	.01065	.01073	.01083	.01105	.01133	.01179	.01055	.01061	.01072	.01084	.01108	.01127	.01179
5/8	.01107	.01114	.01121	.01129	.01139	.01160	.01189	.01235	.01111	.01117	.01128	.01140	.01161	.01183	.01235
21/32	.01161	.01170	.01175	.01183	.01193	.01214	.01245	.01289	.01166	.01171	.01182	.01194	.01218	.01237	.01289
11/16	.01216	.01223	.01230	.01238	.01248	.01269	.01298	.01344	.01220	.01226	.01237	.01249	.01272	.01292	.01344
23/32	.01269	.01276	.01283	.01291	.01301	.01322	.01351	.01397	.01273	.01279	.01290	.01302	.01326	.01345	.01397
3/4	.01324	.01332	.01338	.01347	.01357	.01378	.01407	.01453	.01329	.01335	.01345	.01358	.01381	.01401	.01453
25/32	.01378	.01386	.01392	.01401	.01411	.01432	.01461	.01507	.01383	.01389	.01399	.01412	.01435	.01455	.01507
13/16	.01433	.01441	.01447	.01456	.01466	.01487	.01516	.01562	.01438	.01443	.01454	.01467	.01490	.01510	.01562
27/32	.01487	.01494	.01501	.01509	.01519	.01540	.01569	.01615	.01491	.01497	.01508	.01520	.01543	.01563	.01615
7/8	.01542	.01550	.01556	.01565	.01575	.01596	.01625	.01671	.01548	.01552	.01563	.01576	.01599	.01619	.01671
29/32	.01596	.01604	.01610	.01619	.01629	.01650	.01679	.01727	.01601	.01606	.01617	.01630	.01653	.01673	.01727
15/16	.01651	.01659	.01665	.01674	.01684	.01705	.01734	.01780	.01655	.01661	.01672	.01685	.01708	.01728	.01780
31/32	.01705	.01712	.01718	.01727	.01737	.01758	.01787	.01833	.01709	.01715	.01725	.01738	.01761	.01781	.01833
1	.01760	.01768	.01774	.01783	.01793	.01814	.01843	.01889	.01765	.01770	.01781	.01794	.01817	.01837	.01889

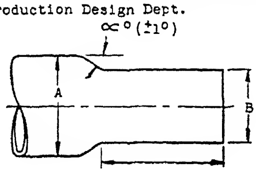
Given: Stock = .065 Steel
Bend Radius = 1/8
Bend Angle = 50°



SWAGING OF TUBES

NON - STRUCTURAL MEMBERS

Swaging shall be specified according to angle desired. Angles "$\propto$" for which dies are available are of 6°, 12° and 18° increments. Drawings shall specify the angle and the swaged diameter required as indicated below. Where reduction is excessive consult Production Design Dept.



STRUCTURAL MEMBERS

For structural design, a standard taper of 18° (included angle = 36°) ONLY shall be used.

Other tapers must NOT be employed without authorization of the Structures Department.

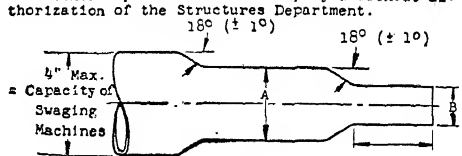


Fig. 1

Outside diameters of swaged tubes (such as "A" and "B") should be given in fractional dimensions with a tolerance of ± 1/64. If they must be given decimally, the tolerances allowed should not be less than ± .005; in such cases a tolerance of ±.007 or ± .008 is preferable for economy of manufacture.

Tolerances: The concentricity of successive steps (see Fig. 1) should not be limited to less than ± .005.

FUEL OIL & COCLANT LINES

Fuel and coolant lines shall NOT be swaged to smaller diameters unless there is no other alternative and shall be approved by the Chief Engineer's Office.

Oil lines may be swaged at the ends.

Typical Applications

Where a swaged tube is shown as a part of a welded assembly (as in Fig. 3 and 4), the dimensions "C" and "D" must always be given as well as the swage angle.

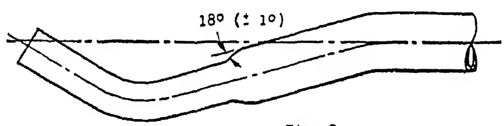


Fig. 2

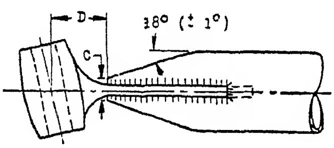


Fig. 3

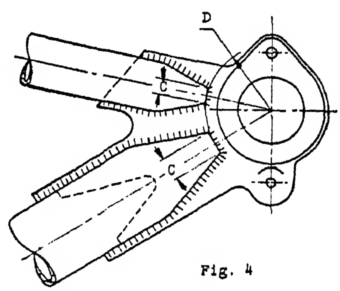


Fig. 4

BEADED TUBE ENDS

Fuel, Oil and Coolant Lines

Beaded ends of fuel and oil tubes of 3/16 diameter and over must be dimensioned according to Fig. 5.

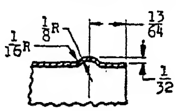


Fig. 5

Exhaust Stack Sections

Beaded ends of exhaust stack sections must conform to the dimensions shown in Fig. 6.

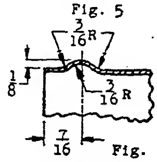


Fig. 6

Beaded Exhaust Manifold Clamps

Fig. 7 shows standard dimensions for beaded clamps used with beaded exhaust stack section ends as shown in Fig. 6.

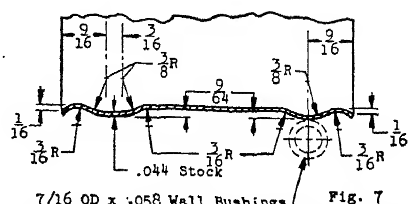


Fig. 7

FIG. 17–4. Swaging of Tubes. (Courtesy of the Curtiss Aeroplane Division, Curtiss-Wright Corporation, Buffalo, N. Y.)

17-3. Aerial Navigation Symbols. — Aerial navigation maps use symbols to give information necessary for use in making flights. The symbols given in Fig. 17-5 are for reference in connection with such maps.

17-4. Weather maps issued daily by the U.S. Department of Commerce, Weather Bureau give information necessary for consideration in making flights. A part of such a map is illustrated in Fig. 17-6. For a thorough treatise on air navigation including airway weather maps and other uses of charts see Special Publication No. 197 of the U.S. Department of Commerce, Coast and Geodetic Survey.

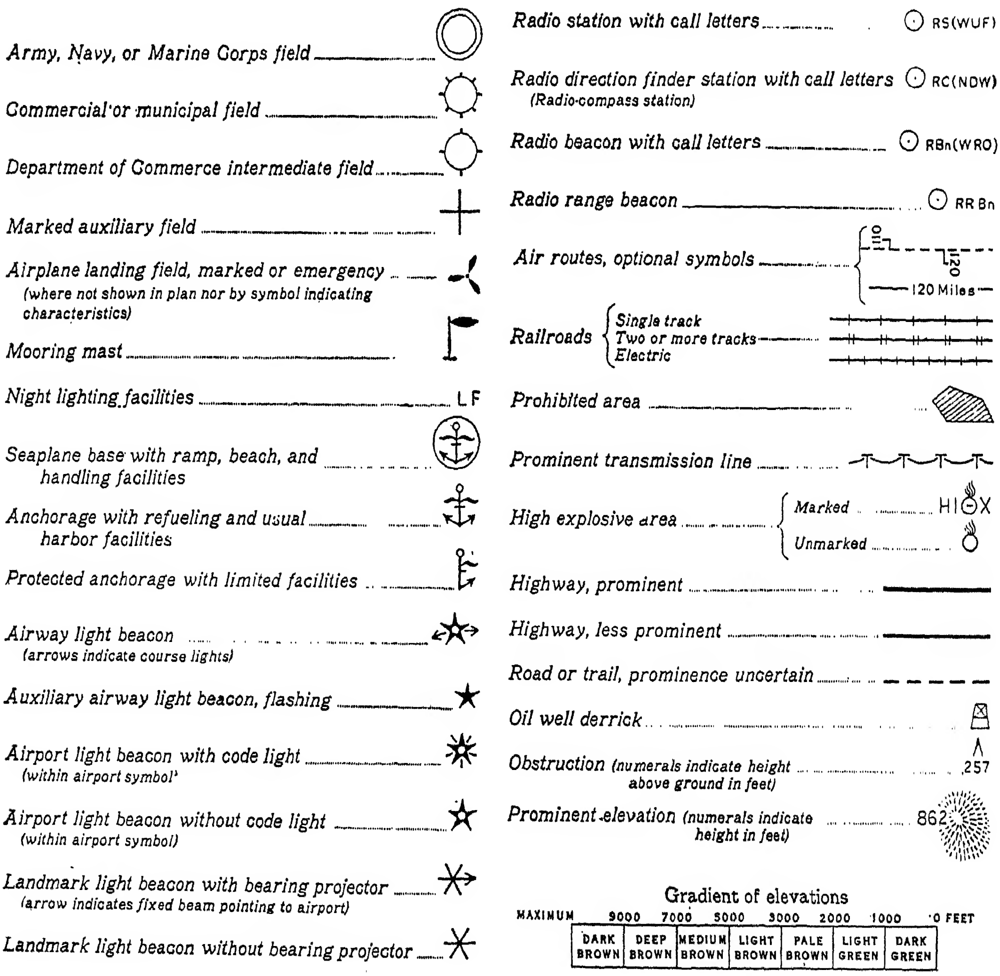


Fig. 17-5. Aeronautical Map Symbols. (From Sheet of Standard Symbols Published by U. S. Geological Survey.)

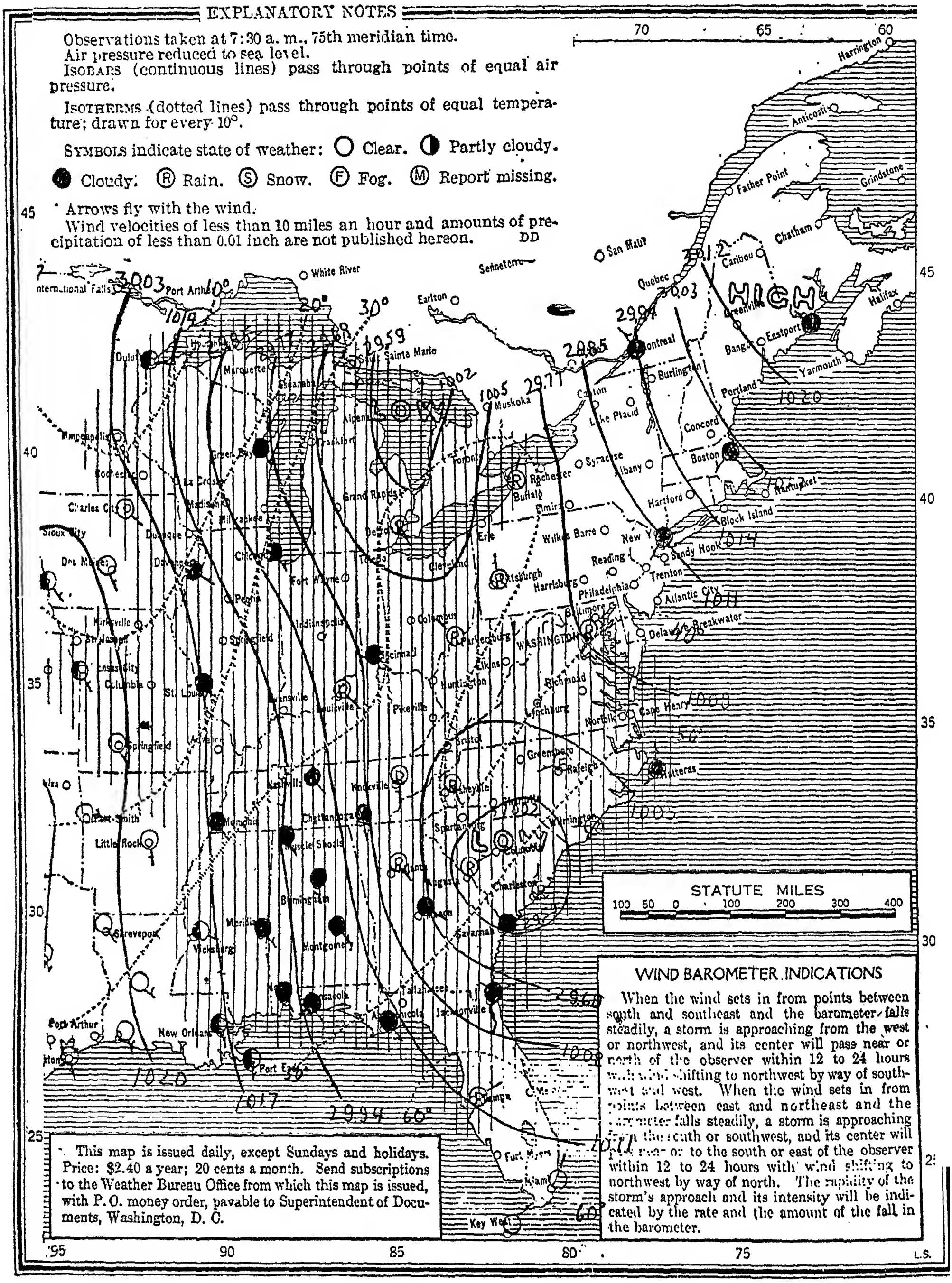


FIG. 17-6. Weather Map. (U. S. Department of Commerce, Weather Bureau.)